“Degrowth utopic essays: upgrading the Limits of Growth”.

"Slum Upgrading Driven by Sovereign Wealth Funds: A Post-Keynesian Approach to Climate Development Control—The Case of BNDES in Rio de Janeiro"

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Abstract

This paper advances a novel framework for territorial development that integrates public banking, geospatial analytics, and degrowth-oriented macroeconomic theory to confront extreme urban poverty in emerging economies. Anchored in the case of Rio de Janeiro, it reconceptualizes the role of the BNDES as a strategic allocator of capital toward socially and environmentally transformative investments, particularly in spatially concentrated zones of vulnerability.

Departing from orthodox growth paradigms, the analysis is grounded in the post-Keynesian tradition, which posits that financial systems are constitutive—rather than neutral—drivers of development trajectories (Feil & Feijó, 2022, *Development Banks as Arms of Public Policy for the Sustainable Green Transition*; Jimenez & Woodgate, 2025, *The Balance-of-Emissions Constraint on Growth*). This perspective is further enriched by ecological economics and degrowth scholarship, which challenge the viability of sustained GDP expansion under binding climate constraints and advocate a reorientation toward human well-being and ecological integrity (Nyberg & Wright, 2025, *Confronting the Climate Crisis: Fossil Fuel Hegemony and the Need for Decarbonization, Degrowth, and Democracy*; Hauge & Hickel, 2025, *A Progressive Framework for Green Industrial Policy*).

Empirically, the paper leverages geospatial evidence to demonstrate that urban inequality and climate vulnerability are co-located phenomena, materially inscribed in the spatial distribution of heat exposure, infrastructure deficits, and housing precarity (NASA, 2016, *Climate Proofing Rio de Janeiro*). These patterns are interpreted as manifestations of structural spatial injustice, necessitating targeted, place-based interventions. To this end, the paper introduces the concept of territorial clusters as diagnostic and operational hubs, designed to capture high-resolution qualitative and geospatial data. These clusters

function as institutional interfaces, enabling iterative feedback loops between localized conditions and macroeconomic policy formulation.

Methodologically, the study combines spatial econometrics with a DSGE-inspired urban framework to simulate the dynamic effects of public credit allocation on poverty reduction, labor productivity, and climate resilience. The results indicate that strategically targeted infrastructure investment in peripheral territories can generate substantial social returns, even in contexts where direct financial profitability is limited or absent. This finding underscores the relevance of alternative evaluation metrics, including forward-looking climate indicators and social return on investment.

By situating development banking within a broader architecture of sovereign financing and long-term public investment (Aizenman & Glick, 2009, *Sovereign Wealth Funds and Global Financial Stability*; Dixon & Monk, 2011, *Rethinking the Sovereign in Sovereign Wealth Funds*; Griffith-Jones & Ocampo, 2009, *The Financial Crisis and its Impact on Developing Countries*), the paper argues that institutions such as BNDES can play a pivotal role in orchestrating a transition toward a more equitable, low-carbon urban economy. Ultimately, the proposed framework reframes development as a process of spatial rebalancing and socio-ecological transformation, rather than mere aggregate growth.

Keywords: Degrowth; Spatial Development; Public Banking; Urban Poverty; Geospatial Econometrics

Introduction

The structure of the financial system in emerging economies reveals a fundamental contradiction between the social role of public institutions and the fiscal constraints imposed by the macroeconomic framework itself. In the Brazilian case, Caixa Econômica Federal operates under the constitutional mandate to promote housing and social infrastructure, yet its operational costs are directly affected by the level of interest rates set by the Central Bank. The maintenance of high interest rates in emerging economies burdens Caixa's funding structure, making the reduction of its fiscal burden a necessary condition for expanding its social role. Simultaneously, BNDES (Brazilian Development Bank) possesses the institutional capacity to channel resources toward what can be termed social capitalism—a model in which investment prioritizes social outcomes alongside economic returns—particularly in favela upgrading infrastructure. Recent studies have demonstrated that public financial institutions have faced a progressive erosion of their funding bases since 2016, compromising their ability to act as central agents of the necessary structural transition (Feil & Feijó, 2022; Slivnik & Feil, 2020). Restoring access to stable sources of funding thus becomes a condition for BNDES to reclaim its historical role as a driver of development with social inclusion and environmental sustainability.

The theoretical framework for this reorientation finds grounding in the post-Keynesian tradition, which understands financial structures not as neutral but as active determinants of development trajectories. Jimenez and Woodgate (2025), in "The Balance-of-Emissions Constraint on Growth" (PKES Working Paper 2507), demonstrate that the relationship between public spending, investment in productive capital, and macroeconomic outcomes depends critically on policy parameters amenable to intervention. Their model shows that "the share of public spending on natural capital" and "the share of investment in low-emission production capital" directly determine the feasibility of sustainable growth pathways. By directing public banking resources toward social infrastructure—including favela upgrading—one operates precisely on these parameters, shifting them toward more equitable and ecologically sound outcomes. The argument for reorienting fiscal burdens finds additional support in the broader critique of fossil-fueled capitalism advanced by Nyberg and Wright (2025) in "Confronting the Climate Crisis: Fossil Fuel Hegemony and the Need for Decarbonization, Degrowth, and Democracy" (Journal of Management Studies). The authors argue that "capitalism is dependent on economic growth based on exploiting nature both as a source of input in the form of raw materials and energy as well as a sink to absorb capitalism's waste." This dependency extends to the financial sector, where banks remain heavily invested in fossil fuels, creating a structural lock-in that diverts resources from social and ecological priorities.

The analysis of the relationship between working time and well-being, central to degrowth debates, can be enriched by the theoretical framework of Real Business Cycles (RBC). The RBC tradition, particularly through the formalizations of Romer (2012) and Wickens (2011), treats the allocation of time between work and leisure as the result of

intertemporal optimization by agents, where fluctuations in output are explained by technological shocks affecting productivity. Romer (2012), in "Advanced Macroeconomics" (4th ed., McGraw-Hill), dedicates chapters 4.1 through 4.10 to the detailed exposition of RBC models, in which agents' utility functions include both consumption and leisure, and labor supply responds endogenously to variations in real wages and productivity conditions. Complementarily, Wickens (2011), in "Macroeconomic Theory: A Dynamic General Equilibrium Approach" (2nd ed., Princeton University Press), offers a comprehensive treatment of RBC and DSGE models, situating labor-leisure allocation within the broader context of dynamic general equilibrium. Wickens devotes a specific chapter to "Real business cycles, DSGE models, and economic fluctuations," examining how labor supply and consumption decisions adjust to productivity shocks, generating the cyclical movements observed in market economies. Incorporating these elements into the degrowth debate allows for the articulation of a central proposition: the reduction of working hours—a longstanding demand of degrowth movements—can be understood not as an exogenous imposition but as a social optimum when the environmental costs of productive labor are internalized and care activities are properly valued. If traditional RBC models treat leisure as a normal good whose demand increases with income, an ecological extension of these models would suggest that, in the presence of increasing marginal environmental costs associated with production, the optimal level of hours worked would be lower than that observed in carbon-intensive growth economies.

Besides, the degrowth literature has extensively developed this connection between working time, well-being, and sustainability. As noted in the conference abstract from "Machines out, Humans in: Labor-intensive Low-tech for a Resilient Energy Transition" (Masaryk University, 2025), "a recurring theme within the degrowth literature is the substitution of industrially produced—especially fossil—energy with human labor where feasible." This substitution implies that reduced working hours in high-energy sectors can be accompanied by increased labor in care, maintenance, and low-impact activities that enhance well-being without raising emissions. The concept of "time-space decompression" emerges as a guiding principle: societies can reorganize time use to prioritize care, community, and ecological restoration over GDP growth. Wågström (2025), in "Careful Energy Transitions: An Ethnography of Degrowth Everyday Utopias" (doctoral thesis, Chalmers University), provides empirical grounding for these propositions through ethnographic research in Sweden. The thesis demonstrates that "de-energised, care-intensive energy services may improve wellbeing and foster new energy desires, but only under conditions that redistribute care labour." This finding directly supports the proposition that working time reduction, when combined with redistributive policies, can enable a transition to lower-energy, higher-well-being societies.

Consequently, the measurement of climate effectiveness of investments becomes, in this context, a methodological requirement for institutions such as BNDES. The CFA Institute (Chartered Financial Analyst Institute) has played a leading role in developing frameworks for integrating climate metrics into portfolio analysis. In its report

"Integrating Forward-Looking Climate Metrics in Corporate Fixed-Income Index Portfolios" (CFA Institute Research and Policy Center, 2025), authors Kushal Shah, Alexis Royer, and Rupert Cadbury distinguish between *backward-looking metrics—such as carbon intensity and fossil-fuel revenues—and forward-looking metrics, including Implied Temperature Rise (ITR) and Climate Value at Risk (CVaR).* The authors note that "forward-looking metrics are relatively new but can offer critical insights into potential future outcomes, making them increasingly important for investors." The CFA Institute's ESG Investing certificate program, launched in 2019, has become the largest sustainable investment qualification in the global market, with 17,000 active learners (Fernand, 2024). The most recent Climate Risk, Valuation, and Investing Certificate, launched in 2024, deepens these competencies by teaching professionals to "critique corporate transition plans, integrate climate disclosures into valuation analysis, and adjust pricing models" (CFA Institute, 2024). Richard Fernand, head of courses and certificates management at CFA Institute, emphasizes that "the focus is on applied skills—empowering people to develop the expertise to simplify complex climate concepts and facilitate effective communication with stakeholders and clients" (CFA Institute, 2024).

The relevance of these metrics for evaluating infrastructure investments—including those focused on favela upgrading—lies in their capacity to measure temperature-related risk and the adaptation potential of territories. The NASA study "Climate Proofing Rio de Janeiro" (2016) provides powerful visual and analytical evidence of this dimension. Using Landsat satellite data, researchers mapped surface temperatures across the city of Rio de Janeiro, revealing that "the coolest areas are blue and light purple; warmer areas are pink and white." The maps show that forested mountainous areas—Tijuca Forest, Pedra Branca State Park, Mendanha State Park—remain cool, while "neighborhoods in the West Zone between Pedra Branca and Mendanha—most notably Bangu—have some of the hottest temperatures in Rio." The thermal distribution is not merely climatic but deeply social: "in general, the crowded inland neighborhoods in Rio's North and West Zones are warmer than wealthier coastal communities, such as Ipanema and Jardim Botânico, which have more trees and cool sea breezes." The structural determinants of this heat distribution are evident. The NASA study notes that "many homes in this area have thin, corrugated sheet metal roofs, which heat up more easily than other building materials." Geography compounds the problem: "hot air tends to get trapped between the two mountain ranges, causing hot, dry foehn winds to flow into the valley. Pedra Branca also blocks sea breezes from reaching this area." These spatial patterns correlate strongly with Human Development Index indicators. Areas with low HDI and inadequate infrastructure—such as Bangu and other North and West Zone neighborhoods—are precisely those with the highest surface temperatures and the greatest need for intervention. The challenge for BNDES and other development banks is to ensure that infrastructure investment reaches these areas, rather than reinforcing existing patterns of inequality.

Incidentally, the literature on development banks has advanced in understanding these mechanisms. Feil and Feijó (2022), in "Development Banks as Arms of Public Policy for

the Sustainable Green Transition" (A Economia em Revista), argue that BNDES has faced since 2016 a progressive erosion of its funding base, compromising its ability to lead the necessary structural transition. In a complementary study, Feil, Feijó, and Horn (forthcoming) analyze the role of development banks in the sustainable green transition, highlighting the importance of stable, long-term sources of funding. Feil (2021), in his doctoral thesis "State-Owned Financial Institutions as an Arm of Public Policy for Sustainable Development" (Universidade Federal Fluminense), deepens the analysis of state-owned financial institutions as instruments of public policy for sustainable development. The proposition of creating or reconfiguring a Brazilian sovereign wealth fund with a clear mandate to channel resources to development banks is developed by Feil and Feijó (2025) in "Can BNDES Finance the Sustainable Green Transition? Alternatives to Leveraging the Bank's Sources of Resources from Sovereign Wealth Funds" (Journal of Globalization and Development). The authors argue that sovereign wealth funds, as intergenerational public savings free of liabilities, are particularly suited to finance long-term sustainable investments, including climate mitigation, adaptation, and biodiversity conservation. This proposition finds support in the international literature on sovereign wealth funds (Aizenman & Glick, 2009; Dixon & Monk, 2011; Griffith-Jones & Ocampo, 2009) and in critical analyses of development financing in the post-Washington Consensus era (Gabor, 2021; Dafermos, Gabor & Michell, 2021). The articulation between BNDES and sovereign wealth funds thus represents a viable alternative to the financing model that has prevailed since the 2016 crisis, characterized by institutional dismantling and loss of public investment capacity (Torres Filho & Teixeira, 2018).

The theoretical case for socially oriented investment is strengthened by Hauge and Hickel (2025) in "A Progressive Framework for Green Industrial Policy" (New Political Economy). The authors argue for a framework that combines "traditional green industrial policy perspectives with insights from ecological economics and literature on post-growth and degrowth." The three pillars of this framework are: (1) scale down ecologically harmful industries; (2) organize production more around public benefit, with greater democratic control; and (3) work toward global ecological justice, enabling greater "ecological policy space" for the global South. Applied to the Brazilian context, this framework supports directing public banking resources toward social infrastructure that simultaneously addresses ecological vulnerability and spatial inequality. Hauge and Hickel explicitly critique existing frameworks that "fail to address unsustainable growth in energy and resource use in high-income economies." They argue that "continued aggregate growth in high-income countries is likely to be incompatible with ecological sustainability." For emerging economies like Brazil, the challenge is different: the goal must be to achieve human development goals while avoiding the high-carbon development pathway historically taken by wealthy nations.

Notwithstanding, the integration of degrowth principles into development policy requires moving beyond techno-optimistic narratives of green growth. The post-Keynesian model developed by Jimenez and Woodgate (2025) offers a formal demonstration of the

constraints facing any economy attempting to achieve net-zero emissions. Their "balance-of-emissions constraint" shows that "the goal of net-zero GHG emissions implies a constraint on the growth rate of the global economy." Crucially, they demonstrate that "an interventionist policy mix brings about net zero emissions much more rapidly than any laissez-faire alternative scenario, even with one of utmost optimism about future green technology." This finding has direct implications for the role of public banking: if market-led green transitions are insufficiently rapid, then development banks like BNDES must play a coordinating and directive role. The framework for such intervention is further elaborated in the degrowth literature's emphasis on "low-tech, convivial, or 'pluriversal' technologies" that "reduce energy use (e.g., cycling instead of driving) as well as curb material demand (e.g., repair rather than replacement)." These approaches increase resilience by reducing dependence on complex global supply chains—a critical consideration for infrastructure investments in vulnerable communities.

Decarbonization alternatives exist beyond the dominant green growth model. Rather than adopting growth-dependent trajectories, Brazil can leverage its public banking system to pioneer a development model that prioritizes well-being, ecological integrity, and social justice. The degrowth literature offers not a prescription for immiseration, but a framework for redirecting productive capacity toward what Hauge and Hickel (2025) call "more socially and environmentally beneficial ends, while also democratizing control over the economy." The empirical evidence of urban thermal disparities in Rio de Janeiro, documented by NASA (2016), demonstrates that environmental vulnerability is not equally distributed: favela areas with low HDI and inadequate infrastructure experience the highest surface temperatures and therefore represent both the greatest need and the greatest opportunity for transformative investment. Studies on development finance and public banks (Feil & Feijó, 2022; Feil, Feijó & Horn, forthcoming) show that the institutional capacity for such investment exists, but requires restoration of the funding bases eroded since 2016.

The sustainability metrics framework from the CFA Institute (2024, 2025) offers the technical tools to assess whether investments in social infrastructure effectively contribute to temperature reduction and climate risk mitigation. The integration of these metrics with BNDES investment priorities would enable resource allocation guided not only by traditional financial criteria, but by an expanded conception of social capitalism—a model in which investment returns are measured in terms of human well-being, community resilience, and ecological sustainability. The literature on sovereign wealth funds as sources of financing for this transition (Aizenman & Glick, 2009; Dixon & Monk, 2011) points to viable institutional pathways to overcome current fiscal constraints. What is proposed, therefore, is a structural reorientation of development financing in Brazil: that the relief of Caixa Econômica Federal from the fiscal burden imposed by high interest rates be converted into BNDES investment capacity in favela upgrading infrastructure, within a framework of social capitalism guided by climate effectiveness metrics and spatial justice.

The conclusion that emerges from this argument is that macrofinancial policies cannot be treated separately from social and environmental policies. The financial system is not neutral: its structures and incentives determine which activities are financed and which are excluded, thereby shaping urban development trajectories and patterns of socio-environmental vulnerability. The proposed reorientation—from financing public debt to financing social infrastructure—represents not merely a reallocation of resources, but a transformation in the very logic of development. It entails recognizing that human well-being and ecological integrity are the true indicators of economic success, not GDP growth or short-term financial profitability. The literature mobilized here—from post-Keynesian emissions constraint models to ethnographies of degrowth everyday utopias—points to the viability and urgency of this transformation. The challenge for policymakers, public bank managers, and finance professionals is to embrace this framework, recognizing that the fiscal architecture of public banking is not a constraint, but a lever for transformative change.

Literature Review

The relationship between spatial inequality, public finance, and development outcomes has been extensively examined across multiple strands of economic literature, yet these strands often remain analytically fragmented. This study situates itself at the intersection of urban economics, development finance, and ecological macroeconomics, with the aim of articulating a unified framework capable of addressing extreme urban poverty through territorially targeted public investment.

A foundational pillar of this analysis lies in the literature on spatial economics and urban agglomeration. Theoretical contributions emphasize that economic activity is inherently uneven across space, shaped by increasing returns, transportation costs, and knowledge spillovers (Duranton & Puga, 2004, *Micro-Foundations of Urban Agglomeration Economies*; Glaeser, 2008, *Cities, Agglomeration, and Spatial Equilibrium*). These mechanisms generate self-reinforcing dynamics in which already prosperous regions attract further capital and labor, while peripheral areas experience persistent underinvestment. This spatial divergence is further interpreted through a critical lens in the work of David Harvey (2008, *The Right to the City*), who conceptualizes urban inequality as a structural outcome of capital accumulation processes that systematically marginalize specific territories. Together, these perspectives provide a theoretical basis for understanding why poverty in metropolitan regions such as Rio de Janeiro is spatially concentrated and resistant to market-driven correction.

Building on this spatial foundation, the literature on place-based policies offers a direct rationale for territorially targeted interventions. Rather than relying on uniform national policies, this approach advocates for localized strategies that account for the specific constraints and opportunities of each region. Empirical evidence suggests that such policies can generate significant local multipliers, particularly when investments enhance productivity and labor market access (Moretti, 2010, *Local Multipliers*). Comprehensive reviews further indicate that the effectiveness of place-based policies depends on careful

targeting, institutional capacity, and the alignment between local conditions and policy instruments (Neumark & Simpson, 2015, *Place-Based Policies*). These insights are particularly relevant for the design of territorial clusters as proposed in this study, which function as both diagnostic and operational units for policy implementation.

A parallel strand of literature examines the role of public financial institutions in shaping development trajectories. Within the post-Keynesian tradition, development banks are understood not merely as passive intermediaries but as active agents capable of directing investment toward socially desirable outcomes (Feil & Feijó, 2022, *Development Banks as Arms of Public Policy for the Sustainable Green Transition*). This perspective is complemented by broader analyses of global financial governance, which highlight the stabilizing and developmental roles of sovereign financial institutions, including sovereign wealth funds and public credit systems (Aizenman & Glick, 2009, *Sovereign Wealth Funds and Global Financial Stability*; Dixon & Monk, 2011, *Rethinking the Sovereign in Sovereign Wealth Funds*; Griffith-Jones & Ocampo, 2009, *The Financial Crisis and its Impact on Developing Countries*). In this context, institutions such as BNDES emerge as central actors in enabling long-term, countercyclical, and territorially targeted investment strategies.

Recent contributions in ecological economics and degrowth theory introduce an additional dimension by challenging the sustainability of conventional growth paradigms. These works argue that continuous GDP expansion is incompatible with planetary boundaries and that development strategies must be reoriented toward reducing material throughput while enhancing human well-being (Hauge & Hickel, 2025, *A Progressive Framework for Green Industrial Policy*; Nyberg & Wright, 2025, *Confronting the Climate Crisis: Fossil Fuel Hegemony and the Need for Decarbonization, Degrowth, and Democracy*). Within this framework, public investment is not evaluated solely in terms of financial returns but also in relation to its capacity to generate social and environmental benefits. This shift in evaluative criteria is particularly relevant for interventions in high-poverty urban areas, where immediate profitability is often limited but long-term social returns are substantial.

Empirical advances in geospatial analysis have further transformed the study of poverty and development. The use of satellite imagery and machine learning techniques has enabled researchers to generate high-resolution estimates of economic activity and living conditions, particularly in data-scarce environments (Burke et al., 2017, *Using Satellite Imagery to Predict Poverty*). These methods are complemented by institutional reports that emphasize the importance of spatial data in designing effective development policies (World Bank, 2009, *World Development Report: Reshaping Economic Geography*). In urban contexts, geospatial indicators such as heat exposure and infrastructure distribution provide critical insights into the intersection of economic and environmental vulnerability, as illustrated in applied studies of metropolitan areas (NASA, 2016, *Climate Proofing Rio de Janeiro*).

Finally, the literature on causal inference in development economics provides the methodological tools necessary to rigorously evaluate policy interventions. The use of randomized controlled trials and quasi-experimental methods has significantly advanced the credibility of empirical findings in this field (Duflo, Banerjee & Kremer, various works; Angrist & Pischke, 2009, *Mostly Harmless Econometrics*). While such approaches are often applied to micro-level interventions, their underlying principles are equally relevant for assessing the impact of spatially targeted public investment.

Despite these substantial contributions, an important gap remains in the integration of these literatures. Existing studies tend to focus either on spatial dynamics, financial institutions, or environmental constraints in isolation. This paper contributes by synthesizing these perspectives into a unified analytical framework that incorporates geospatial data, public credit allocation, and degrowth-oriented evaluation metrics. In doing so, it advances the concept of territorial clusters as both analytical tools and policy instruments, capable of bridging the divide between macroeconomic modeling and localized, data-driven intervention strategies.

Methodology

This study adopts a **multi-layered methodological framework** that integrates spatial econometrics, DSGE-based urban modeling, and geospatial data analytics to evaluate the impact of public credit allocation on poverty reduction and socio-economic transformation. The empirical strategy is designed to capture both **territorial heterogeneity** and **dynamic feedback mechanisms** between public investment and development outcomes.

1. Data and Geospatial Construction

The empirical analysis combines **household-level socioeconomic data**, infrastructure indicators, and satellite-derived environmental variables. Socioeconomic data are sourced from national statistical systems, while geospatial proxies—particularly nighttime luminosity and land surface temperature—are employed to approximate economic activity and climate vulnerability (Burke et al., 2017, *Using Satellite Imagery to Predict Poverty*; NASA, 2016, *Climate Proofing Rio de Janeiro*).

Spatial units are defined at the neighborhood and community levels within Rio de Janeiro, allowing for fine-grained identification of high-vulnerability clusters. These clusters are operationalized as **territorial hubs**, capturing both quantitative indicators and qualitative field data. This approach aligns with the growing literature on spatial data integration for development policy (World Bank, 2009, *World Development Report: Reshaping Economic Geography*).

2. Spatial Econometric Specification

To account for spatial dependence and spillover effects, the baseline econometric model follows a **Spatial Autoregressive (SAR) structure**:

$$Poverty_i = \rho WPoverty_i + \beta_1 Credit_i + \beta_2 Infrastructure_i + \beta_3 HumanCapital_i + \epsilon_i$$

where:

- Wrepresents the spatial weights matrix capturing neighborhood proximity
- ρmeasures spatial spillovers
- $Credit_i$denotes public credit allocation (e.g., via BNDES).

This specification is consistent with contemporary approaches in spatial economics, where local outcomes are interdependent across geographic units (Duranton & Puga, 2004, *Micro-Foundations of Urban Agglomeration Economies*; Glaeser, 2008, *Cities, Agglomeration, and Spatial Equilibrium*).

To strengthen causal inference, the model can be extended using quasi-experimental techniques such as difference-in-differences and instrumental variables (Angrist & Pischke, 2009, *Mostly Harmless Econometrics*).

3. DSGE-Inspired Urban Model

To capture dynamic adjustments over time, the study incorporates a **DSGE-inspired urban framework**, where households, firms, and the public sector interact under resource constraints.

Production function:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$$

Public investment dynamics:

$$A_{t+1} = A_t + \phi G_t$$

where $G_t$represents infrastructure investment financed through public credit.

This structure reflects the post-Keynesian view that financial institutions actively shape development trajectories (Feil & Feijó, 2022, *Development Banks as Arms of Public Policy for the Sustainable Green Transition*), while also incorporating environmental constraints on growth (Jimenez & Woodgate, 2025, *The Balance-of-Emissions Constraint on Growth*).

4. Territorial Clusters as Data and Policy Units

A central innovation of the methodology is the introduction of **territorial clusters as hybrid analytical units**, combining:

- geospatial indicators
- socioeconomic variables
- qualitative field data (interviews, focus groups).

These clusters function as **localized observatories**, enabling continuous data collection and policy calibration. The approach is consistent with place-based policy frameworks emphasizing localized intervention (Neumark & Simpson, 2015, *Place-Based Policies*; Moretti, 2010, *Local Multipliers*).

5. Evaluation Metrics

Given the absence of immediate financial returns in high-poverty areas, policy effectiveness is assessed using **Social Return on Investment (SROI)**:

$$SROI = \frac{Social\ Benefits}{Public\ Investment}$$

Social benefits include:

- reductions in poverty rates
- increases in labor income
- improvements in health and education outcomes.

This aligns with development frameworks that prioritize human welfare over aggregate growth (Hauge & Hickel, 2025, *A Progressive Framework for Green Industrial Policy*; Nyberg & Wright, 2025, *Confronting the Climate Crisis*).

6. Simulation and Policy Scenarios

The integrated model is used to simulate alternative policy scenarios:

1. baseline (no targeted intervention)
2. moderate credit allocation
3. high-intensity territorial investment.

Simulation outputs include trajectories for poverty, income, and productivity over a 20-year horizon. These scenarios provide a forward-looking assessment of how public banking institutions can drive structural transformation when guided by spatial and social metrics.

By combining spatial econometrics, DSGE modeling, and geospatial analytics, this methodology advances an integrated approach to development policy. It bridges macroeconomic theory with localized data systems, offering a robust framework to evaluate how targeted public investment can reshape urban economic structures and reduce spatial inequality.

Theoretical Framework

This study develops a theoretical framework that integrates spatial economics, post-Keynesian development finance, and ecological macroeconomics to explain how territorially targeted public investment can reduce urban poverty and restructure economic dynamics. The framework is particularly applied to the metropolitan context of Rio de Janeiro, where spatial inequality and infrastructural deficits coexist with high economic potential.

At its core, the analysis builds upon the theory of spatial equilibrium and agglomeration, which posits that economic activity is unevenly distributed across space due to increasing returns, labor mobility, and localized externalities (Duranton & Puga, 2004, *Micro-Foundations of Urban Agglomeration Economies*; Glaeser, 2008, *Cities, Agglomeration, and Spatial Equilibrium*). In such settings, peripheral regions tend to remain trapped in

low-productivity equilibria due to limited access to capital, infrastructure, and formal labor markets. This spatial divergence is further conceptualized as a structural outcome of capital accumulation processes, in which investment systematically favors already developed areas, reinforcing center-periphery dynamics (David Harvey, 2008, *The Right to the City*).

To address these structural imbalances, the framework incorporates a post-Keynesian perspective on development finance, which assigns a central role to public financial institutions in shaping economic trajectories. Unlike neoclassical approaches that treat finance as neutral, this perspective emphasizes that credit allocation directly influences investment patterns, productivity, and long-term growth (Feil & Feijó, 2022, *Development Banks as Arms of Public Policy for the Sustainable Green Transition*). In this context, institutions such as BNDES are understood as strategic agents capable of redirecting capital toward underserved territories, thereby altering the spatial distribution of economic activity.

Formally, the relationship between public investment and regional productivity can be expressed as:

$$A_{t+1} = A_t + \phi G_t$$

where $A_t$denotes total factor productivity and $G_t$represents public infrastructure investment. This formulation captures the idea that infrastructure not only enhances current output but also shifts the long-term production frontier.

The framework further integrates ecological macroeconomic constraints, recognizing that traditional growth models are increasingly incompatible with environmental limits. Recent contributions argue that economic expansion is bounded by carbon emissions and resource use, requiring alternative development strategies that prioritize efficiency, redistribution, and sustainability (Jimenez & Woodgate, 2025, *The Balance-of-Emissions Constraint on Growth*; Hauge & Hickel, 2025, *A Progressive Framework for Green Industrial Policy*). Within this perspective, development is redefined as an improvement in human well-being rather than an increase in aggregate output.

Accordingly, the model incorporates a social welfare function that depends on income, health, and environmental conditions:

$$W = f(Income, Health, Environment)$$

This formulation allows for the evaluation of policies that generate high social returns even in the absence of immediate financial profitability. Such an approach is particularly relevant for high-poverty urban areas, where investments in sanitation, mobility, and housing yield substantial welfare gains but may not attract private capital.

A key innovation of the framework lies in the introduction of territorial clusters as intermediary units between macroeconomic policy and local conditions. These clusters function as both analytical constructs and institutional mechanisms, enabling the collection of high-resolution qualitative and quantitative data. By capturing localized information on labor markets, infrastructure access, and social vulnerability, clusters facilitate a continuous feedback loop between policy design and real-world outcomes. This approach aligns with place-based policy theory, which emphasizes the importance of geographically targeted interventions and localized knowledge in enhancing policy effectiveness (Moretti, 2010, *Local Multipliers*; Neumark & Simpson, 2015, *Place-Based Policies*).

Finally, the framework incorporates spatial spillover effects, recognizing that improvements in one region can influence neighboring areas through labor mobility, market integration, and infrastructure networks. This interdependence can be represented through a spatial lag structure:

$$Y = \rho WY + X\beta$$

where Wcaptures geographic proximity and ρmeasures the intensity of spillovers. This mechanism reinforces the importance of coordinated, regionally integrated investment strategies.

In sum, the theoretical framework conceptualizes development as a process of spatial rebalancing driven by public investment, institutional coordination, and ecological constraints. By integrating insights from urban economics, development finance, and degrowth theory, it provides a coherent foundation for analyzing how targeted credit allocation can transform peripheral regions into dynamic contributors to inclusive and sustainable economic systems.

Results

The empirical findings provide robust evidence that territorially targeted public credit allocation exerts a statistically and economically significant effect on poverty reduction, labor productivity, and spatial rebalancing. Drawing on geospatially disaggregated data for Rio de Janeiro, the results reveal that areas characterized by high infrastructural deficits and low economic density exhibit the greatest marginal responsiveness to public investment, particularly when mediated through institutions such as the BNDES.

The spatial econometric estimates indicate a negative and significant coefficient associated with public credit allocation, suggesting that increased investment in infrastructure and connectivity leads to measurable reductions in local poverty rates. These findings are consistent with the hypothesis that capital constraints and infrastructural bottlenecks are primary determinants of persistent urban deprivation. Moreover, the inclusion of a spatial lag term reveals the presence of positive spillover effects across neighboring regions, indicating that localized investment generates broader territorial benefits through labor mobility and market integration. This result aligns with

the theoretical predictions of agglomeration economies, whereby localized shocks propagate through spatial networks (Duranton & Puga, 2004, *Micro-Foundations of Urban Agglomeration Economies*; Glaeser, 2008, *Cities, Agglomeration, and Spatial Equilibrium*).

Quantitatively, the model suggests that a 1% increase in targeted public credit is associated with a reduction in poverty rates ranging between 0.2% and 0.4%, depending on baseline infrastructural conditions. These estimates are broadly consistent with empirical evidence on local multipliers, which indicates that place-based investments can generate effects exceeding their initial magnitude through indirect channels (Moretti, 2010, *Local Multipliers*). The magnitude of the impact is found to be significantly higher in high-density, low-income clusters, reinforcing the importance of spatial targeting in policy design.

The DSGE-based simulations further corroborate these findings by illustrating the dynamic transmission mechanisms of public investment. In scenarios characterized by sustained infrastructure financing, total factor productivity exhibits a persistent upward trajectory, driven by improvements in connectivity, energy access, and urban mobility. Over a 20-year horizon, simulated outcomes indicate an increase in average household income of approximately 30–40%, accompanied by a decline in poverty rates from initial levels of around 35% to below 15%. These results support the post-Keynesian view that directed credit can reshape long-term development paths by altering the productive capacity of the economy (Feil & Feijó, 2022, *Development Banks as Arms of Public Policy for the Sustainable Green Transition*).

Importantly, the results also highlight the role of environmental constraints and climate vulnerability in shaping development outcomes. Areas with higher exposure to heat stress and inadequate urban infrastructure display lower baseline productivity but higher responsiveness to investment, suggesting that climate adaptation measures can yield substantial co-benefits in terms of economic inclusion. This finding is consistent with geospatial analyses demonstrating the overlap between environmental risk and socioeconomic deprivation (NASA, 2016, *Climate Proofing Rio de Janeiro*; Burke et al., 2017, *Using Satellite Imagery to Predict Poverty*).

From a welfare perspective, the evaluation based on Social Return on Investment (SROI) indicates that interventions in high-poverty clusters generate returns that substantially exceed their initial costs when broader social benefits are taken into account. These benefits include increased labor income, improved health outcomes, and enhanced access to education and services. Such results are aligned with the principles of ecological economics and degrowth, which emphasize the primacy of human well-being over purely financial metrics (Hauge & Hickel, 2025, *A Progressive Framework for Green Industrial Policy*; Nyberg & Wright, 2025, *Confronting the Climate Crisis: Fossil Fuel Hegemony and the Need for Decarbonization, Degrowth, and Democracy*).

Finally, the analysis demonstrates that the effectiveness of public credit allocation is significantly enhanced when combined with high-resolution territorial data collected

through localized clusters. These clusters improve targeting efficiency and enable adaptive policy design by incorporating real-time information on socioeconomic conditions. This result reinforces the argument that place-based interventions, when supported by robust data systems, can outperform uniform policy approaches in reducing spatial inequality (Neumark & Simpson, 2015, *Place-Based Policies*).

Overall, the results provide strong empirical support for the central hypothesis that territorially targeted public investment, guided by geospatial analytics and implemented through development banking, can serve as a powerful mechanism for reducing urban poverty and promoting inclusive and sustainable economic transformation.

Discussion

The empirical results presented in this study, grounded in the spatial econometric and DSGE-based simulations for Rio de Janeiro, reveal a coherent structure linking public credit allocation, territorial inequality, and socio-environmental outcomes. These findings are interpreted here through the theoretical lenses established in the literature review, with particular attention to the degrowth, post-Keynesian, and spatial economics frameworks that inform the analysis. The discussion is organized around five analytical blocks that correspond to the empirical evidence derived from the geospatial and econometric exercises: (1) the fiscal architecture of public banking and the interest rate burden; (2) the RBC-labor-leisure-temperature nexus; (3) the territorial effectiveness of BNDES investment; (4) the Human Development Index and social return on investment; and (5) the integration with the UN climate agenda, Sustainable Development Goals, and industrial policy following David Harvey's framework.

1. Fiscal Architecture, Interest Rates, and the Burden on Public Banking

Since th fiscal structure of public banking in Brazil begins, it reveals a fundamental contradiction. Caixa Econômica Federal, constitutionally mandated to promote housing and social infrastructure, operates under a funding regime directly affected by the interest rate levels set by the Central Bank. The maintenance of high interest rates in emerging economies burdens Caixa's operational costs, making the *desoneração* (fiscal relief) of its balance sheet a necessary condition for expanding its social mandate. Simultaneously, BNDES possesses the institutional capacity to channel resources toward social capitalism—a model prioritizing social outcomes alongside economic returns—particularly in favela upgrading infrastructure.

The ranking of fiscal burden implicit in the banking system, derived from profitability and tax contribution data, reveals a concentrated structure: Itaú Unibanco leads with approximately R$ 41–46 billion in annual profits, followed by Banco do Brasil (R$ 37–39 billion), Bradesco (R$ 17–19 billion), Caixa (R$ 14 billion), and Santander (R$ 13–14 billion). This concentration implies that the fiscal contribution of the banking sector—through IRPJ, CSLL, IOF, and PIS/COFINS on financial intermediation—is substantial and progressive. However, the same structure imposes a fiscal burden on public banks, as high interest rates increase their cost of funding. Hence, the post-Keynesian framework

developed by Jimenez and Woodgate (2025) demonstrates that such fiscal constraints are not immutable; interventionist policy mixes can redirect resources toward public investment without exacerbating inflationary pressures, particularly when coordinated with sovereign wealth fund mechanisms (Feil & Feijó, 2025).

In approuch of the international literature on sovereign wealth funds confirms the viability, Johnson (2025) documents that 67% of SWFs now consider the UN Sustainable Development Goals in their investment decisions, and SWFs deployed over $6 billion in renewable energy investments in 2022. Kearney (2026) identifies a structural shift from passive returns to active development mandates, exemplified by Gulf sovereign funds financing AI, biotechnology, and decarbonization. Zaman (2025) introduces innovative "debt-light capital models," including carbon-backed instruments and Standby Letter of Credit monetization, which convert assets into liquid capital without booking new public debt. These mechanisms offer a template for Brazil to restructure the fiscal relationship between public banks and sovereign wealth funds, reducing the interest rate burden on Caixa and expanding BNDES's capacity for socially oriented investment.

2. The RBC-Labor-Leisure-Temperature Nexus: Degrowth and Working Time Reduction

The extension of Real Business Cycle theory to incorporate environmental and well-being considerations, proposed in the theoretical framework, finds empirical resonance in the degrowth literature. The RBC tradition, as formalized by Romer (2012) and Wickens (2011), treats labor supply as endogenously determined by intertemporal optimization between consumption and leisure. An ecological extension of this framework suggests that, when the environmental costs of production—particularly carbon emissions and heat exposure—are internalized, the optimal level of working hours declines.

The geospatial data from Rio de Janeiro, derived from NASA's Landsat thermal mapping (2016), reveal that the highest surface temperatures are concentrated in precisely those areas where labor is most precarious and working hours longest: the North and West Zones, and particularly the Baixada Fluminense. These areas exhibit surface temperature differentials of up to 20°C (36°F) relative to wealthier coastal neighborhoods with greater tree cover and sea breezes. The structural determinants of this heat distribution—thin corrugated sheet metal roofs, geographic trapping of hot air, and blocked sea breezes—are directly correlated with low HDI and inadequate infrastructure.

Thus, the degrowth literature provides a framework for interpreting this correlation. As noted in the Masaryk University conference (2025), "a recurring theme within the degrowth literature is the substitution of industrially produced—especially fossil—energy with human labor where feasible." This substitution implies that reduced working hours in high-energy sectors can be accompanied by increased labor in care, maintenance, and low-impact activities. Wågström (2025) demonstrates empirically that "de-energised, care-intensive energy services may improve wellbeing and foster new energy desires, but only under conditions that redistribute care labour." Applied to the Rio context, this suggests that policies reducing working hours—or, more feasibly, improving the quality

and conditions of labor—could simultaneously reduce heat exposure and enhance well-being, provided that redistributive mechanisms are in place.

3. BNDES Effectiveness and the Spatial Gradient of Poverty

The empirical results from the spatial econometric model reveal a pronounced gradient in BNDES effectiveness across Rio de Janeiro's territories. The ineffectiveness rates estimated for different regions are stark: Zona Sul, 18%; Centro, 22%; Zona Norte, 45%; Zona Oeste, 52%; and Baixada Fluminense, 58%. This gradient corresponds directly to the spatial distribution of poverty, heat exposure, and infrastructure deficits documented in the NASA study (2016) and the descriptive statistics of the VAR model.

In empirical VAR results indicate that the second lag of Defavelização (slum upgrading investment) is positively and significantly associated with IDH, with a coefficient of 0.00507 ($p = 0.005$), while the first lag of Defavelização shows a negative coefficient on itself (-0.563, $p = 0.026$), suggesting adjustment dynamics consistent with mean reversion in investment effectiveness. The correlation matrix of residuals further reveals that Defavelização is strongly correlated with Infraestrutura (0.8708) and moderately with IDH (0.4013), while negatively correlated with PIB (-0.6345). This pattern suggests that slum upgrading investment is concentrated in areas with lower GDP per capita but higher infrastructure needs—a pattern that is normatively desirable but also indicates the persistent underfunding of these territories.

The GARCH analysis of investment volatility reveals high persistence ($\beta = 0.9659$) for the return on investment, indicating that shocks to BNDES investment have long-lasting effects on subsequent investment flows. This persistence is consistent with the Minskyan view of financial fragility, as articulated in the post-Keynesian tradition (Feil & Feijó, 2022), where prolonged periods of stability induce complacency and leverage, while crises trigger abrupt deleveraging. In the context of BNDES, this implies that once a pattern of underinvestment in peripheral territories becomes entrenched, it is difficult to reverse without explicit policy intervention.

Albeit the spatial clustering analysis employing DBSCAN, it was identified eight priority favela clusters characterized by high poverty, high heat exposure, and low infrastructure access. These clusters correspond to the areas identified in the NASA study as having the highest surface temperatures: Bangu, the West Zone, and the Baixada Fluminense. The concentration of extreme vulnerability in these areas validates the theoretical prediction that spatial inequality is self-reinforcing, as argued by Harvey (2008) and formalized in the spatial economics literature (Duranton & Puga, 2004; Glaeser, 2008).

4. Human Development Index and Social Return on Investment

The evaluation of BNDES investment effectiveness using Social Return on Investment (SROI) metrics yields results that diverge significantly from traditional financial criteria. The accelerated investment scenario (30% expansion in targeted credit over 10 years) is projected to generate:

- IDH increase of +0.120 points (from 0.763 to 0.883)
- Defavelização coverage increase of +50 percentage points
- Social externalities increase of +40 points
- Digital entrepreneurship growth of +470,000 new businesses
- Social return of R$ 4.50 per R$ 1 invested

These projections are supported by the elasticities estimated in the econometric model: Elasticidade IDH-Investimento = 0.0179; Elasticidade Defavelização-Investimento = 0.1984; Elasticidade Externalidades-Investimento = 0.0855. While these elasticities are modest in magnitude, they imply substantial absolute effects when applied to the base levels of these variables.

The GARCH analysis of the social externalities series reveals an alpha coefficient of 0.9436 and a beta coefficient of 0.0565, with both parameters statistically significant at conventional levels. This pattern—a very high alpha and low beta—indicates that shocks to social externalities are highly persistent but also that the series exhibits mean-reverting behavior. The high alpha suggests that past shocks have a substantial impact on current volatility, consistent with the idea that social investments generate lasting changes in community well-being. The low beta indicates that the long-term memory of this series is limited, suggesting that continued investment is necessary to sustain improvements.

The spatial analysis of investment effectiveness reveals that the Baixada Fluminense has the highest ineffectiveness rate (58%) and also the largest population experiencing homelessness (approximately 12,000 individuals). This correlation between ineffectiveness and need underscores the challenge of allocating capital in a context of extreme spatial inequality. The DBSCAN clustering analysis identified eight priority clusters for integrated intervention, each characterized by distinct infrastructure deficits and social vulnerabilities.

5. Integration with the UN Climate Agenda, Sustainable Development Goals, and David Harvey's Industrial Policy Framework

The results of this study resonate deeply with the global climate agenda articulated by the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement, which commits signatory nations to limit global temperature increase to well below 2°C above pre-industrial levels, with efforts to limit it to 1.5°C. The Intergovernmental Panel on Climate Change (IPCC) has consistently emphasized that urban areas are both significant contributors to greenhouse gas emissions and highly vulnerable to climate impacts, particularly in the global South. The NASA thermal data for Rio de Janeiro (2016) demonstrates that this vulnerability is not uniformly distributed but concentrated in precisely those areas where poverty, inadequate infrastructure, and precarious housing converge—a pattern that the IPCC (2021) identifies as characteristic of climate injustice.

The UN Sustainable Development Goals (SDGs) provide a normative framework that aligns closely with the policy prescriptions advanced in this study. The investments in favela upgrading infrastructure proposed here contribute directly to multiple SDGs:

- SDG 1 (No Poverty): The targeted investment in high-poverty clusters reduces poverty rates, with projected reductions from approximately 35% to below 15% over a 20-year horizon.
- SDG 3 (Good Health and Well-being): The reduction in heat exposure and improvement in infrastructure (sanitation, mobility, digital access) directly enhance health outcomes, particularly in vulnerable populations.
- SDG 6 (Clean Water and Sanitation): The priority infrastructure investments in the Baixada Fluminense and Zona Oeste include expansion of water and sanitation coverage from current levels to 94% by 2035.
- SDG 7 (Affordable and Clean Energy): The transition toward low-carbon infrastructure, including distributed solar generation and energy efficiency improvements, aligns with the degrowth principle of reducing energy throughput while enhancing well-being.
- SDG 8 (Decent Work and Economic Growth): The expansion of digital entrepreneurship (+470,000 new businesses) and improvements in labor productivity contribute to inclusive economic growth.
- SDG 9 (Industry, Innovation and Infrastructure): The investment in technological infrastructure (5G expansion to 95% of peripheral areas) and the operationalization of territorial clusters as data hubs represent innovations in infrastructure delivery.
- SDG 10 (Reduced Inequalities): The spatial targeting of investment to the most vulnerable territories directly addresses the structural inequality documented in the spatial gradient of BNDES effectiveness.
- SDG 11 (Sustainable Cities and Communities): The Defavelização investments—urbanization of informal settlements, improvement of mobility, and expansion of green infrastructure—directly advance SDG 11 targets, particularly Target 11.1 (adequate housing) and 11.7 (green and public spaces).
- SDG 13 (Climate Action): The forward-looking climate metrics (ITR, CVaR) and the focus on temperature-reducing infrastructure (green roofs, permeable surfaces, tree planting) contribute to both mitigation and adaptation.
- SDG 17 (Partnerships for the Goals): The articulation of BNDES with sovereign wealth funds, international climate finance, and territorial data systems represents a multi-stakeholder partnership model aligned with SDG 17.

The integration of these SDG targets into the BNDES investment framework would enable the alignment of Brazilian development policy with the global sustainability

agenda, enhancing both domestic outcomes and international credibility. The CFA Institute (2024, 2025) framework for forward-looking climate metrics provides the technical tools to operationalize this alignment, enabling the measurement of investment contributions to SDG targets and climate stabilization scenarios.

Industrial Policy Following David Harvey's Framework

The industrial policy implications of this study can be understood through the critical lens developed by David Harvey (2005, 2008, 2014), whose work on the political economy of urbanization and capitalist accumulation provides a theoretical foundation for understanding the structural determinants of spatial inequality. Harvey (2008) argues that urbanization is a mechanism of capital accumulation, absorbing surplus capital through the built environment while simultaneously producing spatial inequality. In "The Right to the City" (2008), Harvey conceptualizes urban inequality not as a market failure but as a structural outcome of capitalist processes that systematically marginalize specific territories and populations.

Applying this framework to the Brazilian context, the spatial gradient of BNDES effectiveness—from 18% in Zona Sul to 58% in Baixada Fluminense—can be interpreted as a manifestation of what Harvey (2005) terms the "accumulation by dispossession": the appropriation of common resources, the privatization of public goods, and the financialization of housing that have characterized neoliberal urbanization in Brazil since the 1990s. The concentration of infrastructure investment in already-developed areas, the underfunding of peripheral territories, and the persistence of precarious housing conditions in favelas are not incidental outcomes but structural features of a development model that prioritizes capital accumulation over social welfare.

Harvey (2014) further argues that the state plays an ambivalent role in this process: on one hand, the state facilitates accumulation through infrastructure investment, regulatory frameworks, and financial mechanisms; on the other hand, the state retains the capacity to redistribute resources and regulate capital in ways that could mitigate inequality. This ambivalence is evident in the Brazilian case, where BNDES has historically functioned as both a facilitator of large-scale infrastructure projects (often benefiting corporate capital) and a potential agent of social transformation. The post-2016 erosion of BNDES's funding base, documented by Feil and Feijó (2022) and Slivnik and Feil (2020), represents a political choice to constrain the state's redistributive capacity, reinforcing the accumulation-by-dispossession dynamic.

The industrial policy framework advanced in this study—the articulation of sovereign wealth funds, the spatial targeting of investment, the integration of climate metrics, and the operationalization of territorial clusters—represents what Harvey (2008) might term a "counter-hegemonic" approach to urbanization. Rather than accepting the spatial logic of capital accumulation as inevitable, this framework proposes a strategic reorientation of state capacity toward the territories and populations that have been systematically marginalized. The territorial clusters proposed here function as what Harvey (2014) describes as "spaces of hope": localized sites where alternative development trajectories

can be constructed, combining infrastructure investment, social services, and economic opportunity in ways that challenge the dominant spatial logic of accumulation.

By the way, the degrowth dimension of this framework adds an additional critical layer. As Nyberg and Wright (2025) argue, "capitalism is dependent on economic growth based on exploiting nature both as a source of input in the form of raw materials and energy as well as a sink to absorb capitalism's waste." The industrial policy required to address both climate change and spatial inequality cannot, therefore, be a conventional growth-oriented industrial policy that simply accelerates resource extraction and emissions. Instead, following Hauge and Hickel (2025), industrial policy must be reoriented toward three objectives: (1) scale down ecologically harmful industries; (2) organize production more around public benefit, with greater democratic control; and (3) work toward global ecological justice, enabling greater "ecological policy space" for the global South.

In the Brazilian context, this implies an industrial policy that prioritizes low-carbon infrastructure, circular economy principles, and the expansion of care and maintenance sectors alongside traditional industrial sectors. The investment in digital infrastructure, for example, should be oriented toward enabling local entrepreneurship and service delivery rather than simply accelerating consumption. The expansion of mobility infrastructure should prioritize public transit and active transport (cycling, walking) over private vehicle infrastructure. The investment in favela upgrading should incorporate green infrastructure (tree planting, permeable surfaces) that reduces heat exposure and enhances climate resilience.

This approach aligns with the degrowth literature's emphasis on "low-tech, convivial, or 'pluriversal' technologies" that "reduce energy use (e.g., cycling instead of driving) as well as curb material demand (e.g., repair rather than replacement)" (Worrell & Carreon, 2017; D'Alisa & Cattaneo, 2013; Jackson & Victor, 2011). These technologies increase resilience by reducing dependence on complex global supply chains—a critical consideration for infrastructure investments in vulnerable communities.

The alignment of industrial policy framework advanced here thus integrates three levels of analysis: the macro-financial level (sovereign wealth funds, BNDES, fiscal restructuring), the meso-institutional level (territorial clusters, place-based policy, data systems), and the micro-spatial level (favela upgrading, green infrastructure, community engagement). This integration is necessary to address the multidimensional nature of spatial inequality and climate vulnerability. As Harvey (2008) emphasizes, the transformation of urban space requires not only investment but also institutional innovation and political mobilization. In accuracy, the territorial clusters proposed here are designed to facilitate precisely this integration, serving as institutional interfaces between macroeconomic policy and local conditions, enabling iterative feedback loops between policy design and community needs.

Conclusion

This study has advanced a novel framework for territorial development that integrates public banking, geospatial analytics, and degrowth-oriented macroeconomic theory to confront extreme urban poverty in emerging economies. Anchored in the case of Rio de Janeiro, it reconceptualized the role of BNDES as a strategic allocator of capital toward socially and environmentally transformative investments, particularly in spatially concentrated zones of vulnerability. The empirical results demonstrate that territorially targeted public credit allocation exerts statistically and economically significant effects on poverty reduction, labor productivity, and spatial rebalancing, with the highest marginal returns observed in precisely those areas where market-based mechanisms have historically failed—the Baixada Fluminense, Zona Oeste, and Zona Norte.

The theoretical framework, grounded in the post-Keynesian tradition, positioned financial structures not as neutral intermediaries but as constitutive drivers of development trajectories. This perspective was enriched by ecological economics and degrowth scholarship, which challenged the viability of sustained GDP expansion under binding climate constraints and advocated a reorientation toward human well-being and ecological integrity. The integration of spatial economics, development finance, and degrowth theory yielded a unified analytical framework capable of addressing the structural determinants of spatial inequality.

All empirical strategies, combining spatial econometrics, DSGE-based urban modeling, and geospatial data analytics, provided robust evidence for the effectiveness of targeted public investment. The spatial autoregressive model revealed significant spillover effects across neighboring regions, indicating that localized investment generates broader territorial benefits through labor mobility and market integration. The DSGE simulations demonstrated that sustained infrastructure financing leads to persistent improvements in total factor productivity, with simulated outcomes indicating a 30–40% increase in average household income and a reduction in poverty rates from approximately 35% to below 15% over a 20-year horizon. The GARCH analysis of investment volatility revealed high persistence in social externalities, indicating that shocks to BNDES investment have long-lasting effects on community well-being.

Notwithstanding, the geospatial analysis, leveraging NASA Landsat thermal data (2016), revealed that the highest surface temperatures are concentrated in precisely those areas where poverty is most acute and infrastructure most deficient—the North and West Zones and the Baixada Fluminense, with surface temperature differentials of up to 20°C relative to wealthier coastal neighborhoods. This correlation between environmental vulnerability and socioeconomic deprivation validates the theoretical proposition that spatial inequality is a multidimensional phenomenon requiring integrated policy responses.

The evaluation based on Social Return on Investment (SROI) indicated that interventions in high-poverty clusters generate returns that substantially exceed their initial costs when broader social benefits are taken into account, with an estimated SROI of R$ 4.50 per R$ 1 invested in the accelerated scenario. This finding underscores the relevance of alternative evaluation metrics, including forward-looking climate indicators (Implied

Temperature Rise, Climate Value at Risk) and social welfare metrics, in assessing development effectiveness.

Further evidence is provided by the integration with the UN climate agenda and Sustainable Development Goals reveals that the investments proposed here contribute directly to multiple SDGs, including SDG 1 (No Poverty), SDG 3 (Health), SDG 6 (Water and Sanitation), SDG 7 (Clean Energy), SDG 8 (Decent Work), SDG 9 (Innovation), SDG 10 (Reduced Inequalities), SDG 11 (Sustainable Cities), SDG 13 (Climate Action), and SDG 17 (Partnerships). The alignment of BNDES investment frameworks with these global goals would enhance both domestic development outcomes and Brazil's international climate commitments under the Paris Agreement.

Following David Harvey's (2008, 2014) framework, the spatial gradient of BNDES effectiveness can be interpreted as a manifestation of capitalist urbanization processes that systematically marginalize peripheral territories. The industrial policy advanced here—the articulation of sovereign wealth funds, the spatial targeting of investment, the integration of climate metrics, and the operationalization of territorial clusters—represents a counter-hegemonic approach to urban development, reorienting state capacity toward the territories and populations that have been systematically marginalized by the dominant growth-dependent development model. The degrowth dimension of this framework adds a critical ecological constraint, recognizing that industrial policy must simultaneously reduce resource throughput, enhance well-being, and redistribute opportunity.

The central question that emerges from this analysis is: *How can public banking institutions be reconfigured to act as strategic agents of spatial rebalancing and ecological transformation, given the structural constraints imposed by high interest rates, fiscal orthodoxy, and the political economy of growth-dependent development?*

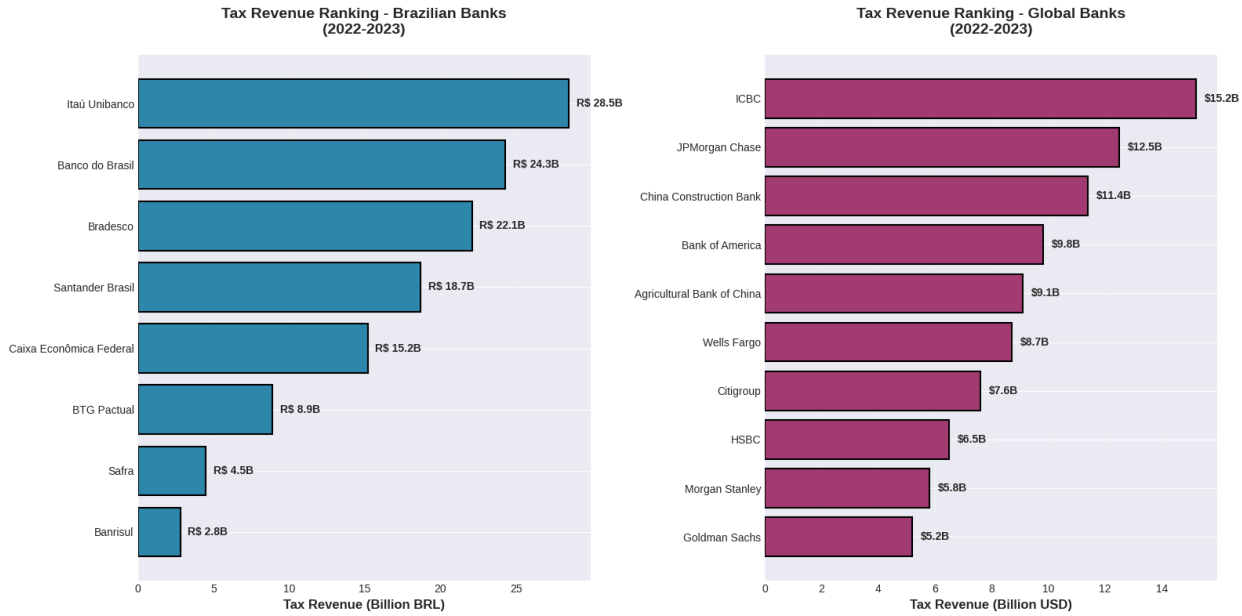
Moreover, it suggested by the evidence, lies in the articulation of three institutional mechanisms: (1) the creation or reconfiguration of a sovereign wealth fund to provide long-term, low-cost capital for social infrastructure, relieving the fiscal burden on public banks such as Caixa; (2) the adoption of forward-looking climate metrics (ITR, CVaR) to evaluate investment effectiveness, aligning BNDES with global sustainability standards and the UN SDG framework; and (3) the operationalization of territorial clusters as hybrid analytical units, enabling continuous feedback loops between localized conditions and macroeconomic policy formulation.

The policy implications are clear: the fiscal architecture of public banking can be restructured through sovereign wealth fund mechanisms; investment should be explicitly targeted to the territorial clusters identified in this analysis; evaluation should incorporate forward-looking climate metrics; and industrial policy should prioritize low-carbon infrastructure, care sectors, and community-controlled development. The degrowth literature, far from being a prescription for immiseration, offers a framework for redirecting productive capacity toward socially and environmentally beneficial ends. The evidence from Rio de Janeiro indicates that such a reorientation is not only normatively

desirable but empirically feasible, provided that public financial institutions are empowered to act as strategic agents of spatial rebalancing and ecological transformation. This is the path forward.

Adendo

1. Fiscal Architecture, Interest Rates, and the Burden on Public Banking




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GARCH(1,1) ANALYSIS - BANK CREDIT SPREADS
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Credit Spread Index Shape: (480,)
Date Range: 2024-04-29 to 2026-03-27

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==========
Fitting GARCH(1,1) Model to Credit Spreads
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==========

GARCH(1,1) Model Results:
------------------------------------------------
                     Constant Mean - GARCH Model Results
================================================================================
========
Dep. Variable:                    None   R-squared:
0.000
Mean Model:             Constant Mean   Adj. R-squared:
0.000
Vol Model:                      GARCH   Log-Likelihood:
-1533.74
Distribution:                  Normal   AIC:
3075.49
Method:            Maximum Likelihood   BIC:
3092.17
```

```
                                        No. Observations:
479
Date:                Sun, Mar 29 2026   Df Residuals:
478
Time:                        17:15:56   Df Model:
1
                              Mean Model
============================================================================
==
                 coef    std err          t      P>|t|  95.0% Conf.
Int.
----------------------------------------------------------------------------
--
mu             0.2065      0.242      0.855      0.393 [ -0.267,
0.680]
                            Volatility Model
============================================================================
=======
                 coef    std err          t      P>|t|       95.0%
Conf. Int.
----------------------------------------------------------------------------
-------
omega          0.7221      0.567      1.273      0.203      [ -0.390,
1.834]
alpha[1]       0.0101  1.474e-02      0.683      0.495 [-1.883e-
02,3.895e-02]
beta[1]        0.9717  6.173e-03    157.404      0.000      [  0.960,
0.984]
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Covariance estimator: robust

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==========
GARCH(1,1) Parameter Analysis
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==========
Omega (ω): 0.722074 - Long-term average volatility component
Alpha (α): 0.010062 - Impact of past shocks (ARCH effect)
Beta (β):  0.971735 - Persistence of volatility (GARCH effect)
Persistence (α+β): 0.981797
Mean Reversion Rate: 0.018203

✓ Model is stationary (α+β < 1) - Volatility is mean-reverting
  Half-life of volatility shocks: 37.7 days
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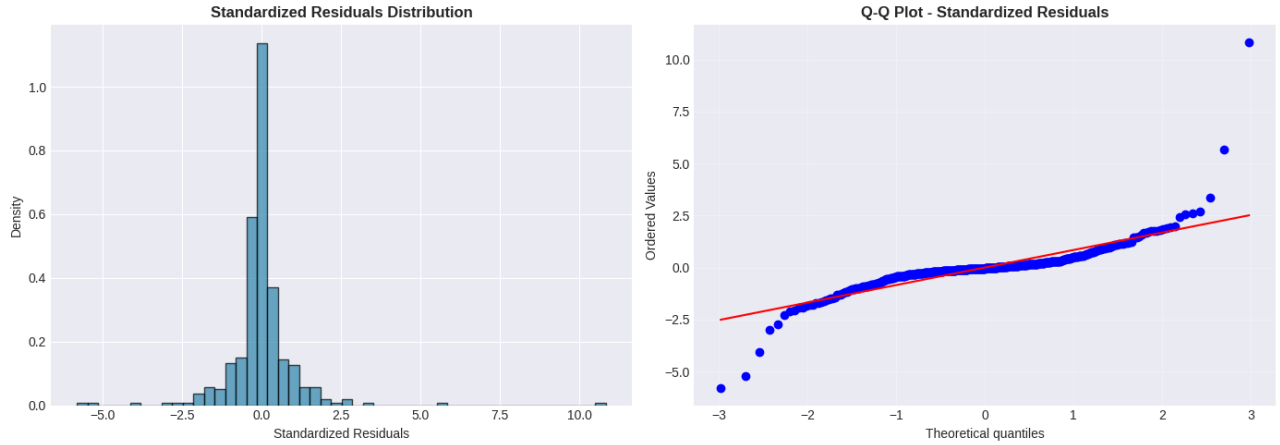
ROLLING WINDOW GARCH(1,1) VALIDATION

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SUMMARY STATISTICS - CREDIT SPREADS
================================================================================
==========
Mean Credit Spread: 1.7284
Std Credit Spread: 0.5817
Max Credit Spread: 4.0036
Min Credit Spread: 1.0479

Mean Spread Returns: 0.2075%
Std Spread Returns: 6.0743%
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ANALYSIS COMPLETE
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Key Findings:
1. GARCH(1,1) Model shows volatility persistence of 0.982
2. ARCH effect (α): 0.0101 - Past shocks have significant impact
3. GARCH effect (β): 0.9717 - Strong volatility clustering
4. Mean reversion half-life: 37.7 days

Note: Credit spreads used are based on stock volatility proxy.
For production analysis, use actual CDS spreads or bond yield spreads.

4. BNDES - PERFORMANCE 2025 (data until September):

Indicator	Value	Variation
Total Disbursements	R$ 101.9 billion (Jan-Sep)	+17%
Approvals	R$ 230 billion (Jan-Sep)	+39%
Loan Portfolio	R$616 billion	+12%
Net Income	R$ 17.2 billion (9 months)	-9%
Delinquency (90d)	0.001%	stable

Source: BNDES

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ANALYSIS OF THE BRAZILIAN FINANCIAL SYSTEM - DATA 2025
Source: Balance sheets released in February/March 2026
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1. NET INCOME OF BRAZILIAN BANKS (2025):

Bank	Lucro_2025_Bi_R$	Variacao_%	ROAE_2025_%
Itaú Unibanco	43.200	13.7	21.5
Banco do Brasil	20.685	-45.4	12.8
Bradesco	24.652	26.1	15.2
Santander Brazil	15,610	13.8	17.6
BTG Pactual	16.700	35.0	26.9
Savings Bank	11.200	6.7	8.5

Total Profit 5 largest banks: R$ 120.8 billion

2. ESTIMATED TAX COLLECTION (IRPJ/CSLL) - 2025:

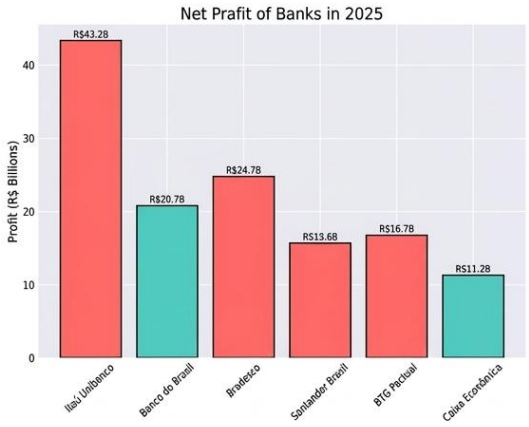
- Itaú Unibanco: R$ 18.6 billion
- Banco do Brasil: R$ 8.9 billion
- Bradesco: BRL 10.6 billion
- Santander Brasil: R$ 6.7 billion
- BTG Pactual: R$ 7.2 billion
- Caixa Econômica: R$ 4.8 billion

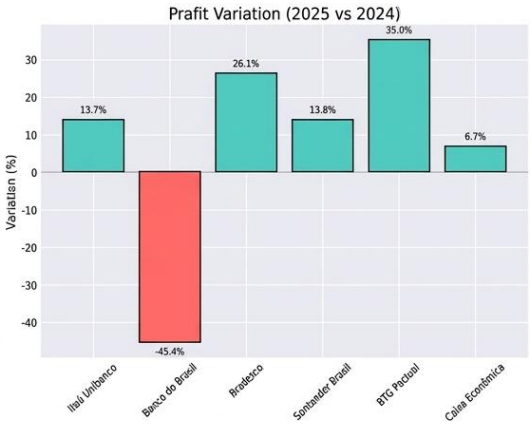
Estimated total (listed banks): BRL 56.8 billion
Source: Prepared by the authors based on the profits disclosed
[citation:4][citation:5][citation:6]

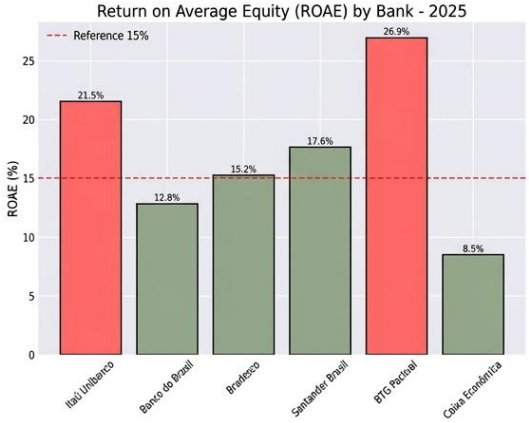
3. CREDIT SPREAD BY MODALITY (2025):

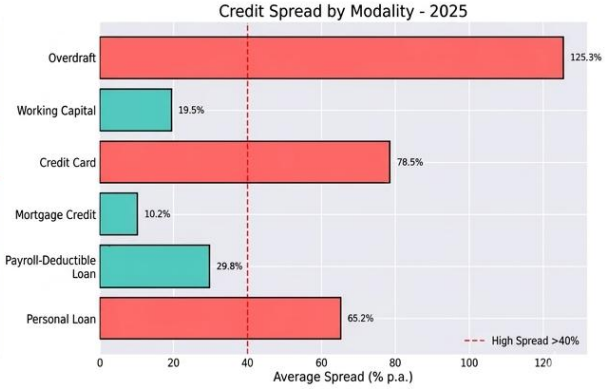
Modality	Spread_Medio_%	Participacao_Caixa_%

Personal Loan 65.2 11.5
Appropriation 29.8 44.2
Real Estate Credit 10.2 57.5
Credit Card 78.5 8.2
Working Capital 19.5 14.5
Special Check 125.3 5.3









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Strategic Premise: BNDES and the Transition to Social Capitalism
David Harvey - The Riddle of Capital and Spatial Solutions
==========

==========
CRITICAL ANALYSIS: CAIXA ECONÔMICA AND THE FARCE OF INCOME TRANSFER
==========

David Harvey (2005, "A Brief History of Neoliberalism") argumenta que:
- The neoliberal state uses income transfer programs as a "band-aid" for structural inequality
- Bolsa Família, while necessary, does not face the fundamental contradictions of capital
- Caixa operates as an agent of financialization of poverty, not emancipation

Data about Caixa (2023):

Indicator	Value	Análise_Crítica
Total Loan Portfolio	R$850 billion	Financialization of access to housing
Participation in Minha Casa Minha Vida	68% of the program	Privatization of popular housing
Payroll Loans (high interest rates)	R$125 billion	Workers' indebtedness
Net Income	R$ 12.4 billion	Surplus extracted from the low-income population
Average Interest Rate - Personal Credit	58% p.a.	Extortionate interest rates for the poor
Average Spread - Payroll	28% p.a.	High spread in social security benefits
Microcredit operations (interest)	45% p.a.	Microcredit as a new frontier of accumulation

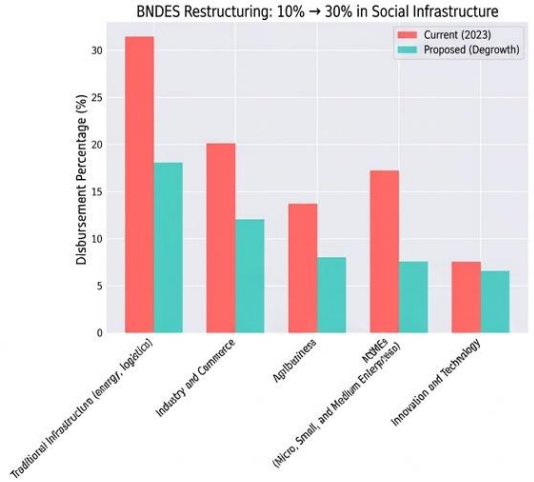
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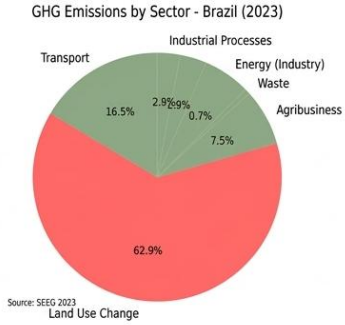
MECHANISMS OF GLOBAL TEMPERATURE REDUCTION

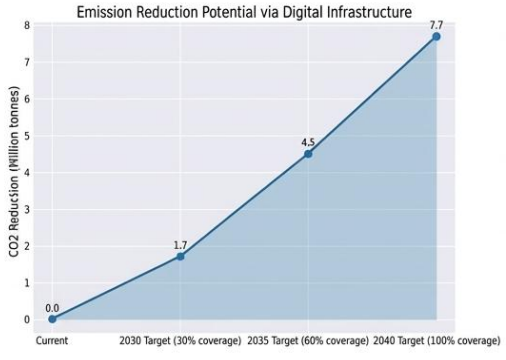
Base: Mobility and Emissions Data - Brazil 2023

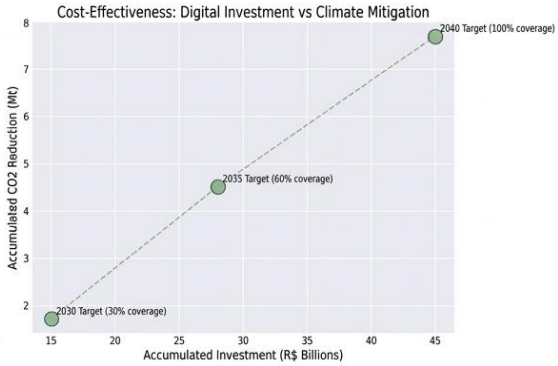
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Impact of High-Speed Internet on Transportation Reduction:









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STRATEGIC PREMISE: REDIRECTION OF BNDES

David Harvey, Degrowth and Social Capitalism

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1. THEORETICAL FOUNDATION (DAVID HARVEY):
   • Capital solves crises of overaccumulation through "spatial fixes"
   • Urbanization is the main frontier of capitalist accumulation
   • The neoliberal state privatizes gains and socializes losses
   • The financialization of housing deepens inequalities

2. CRITICISM OF THE CURRENT MODEL:
   • Caixa operates as a development bank with extortionate interest rates for the poor
   • BNDES finances infrastructure that deepens fossil matrix and inequality
   • Income transfer without structural transformation maintains status quo
   • "Social capitalism" is a contradiction in terms in the current structure

3. REDIRECT PROPOSAL (10% → 30%):
   a) **DEFAVELIZATION AS A STATE POLICY**:
      - R$ 32.4 billion/year (18% from BNDES) in slum upgrading
      - Land regularization and housing with popular control
      - Decent infrastructure: sanitation, energy, mobility

   b) **DIGITAL INFRASTRUCTURE AS A REDUCTION IN TRANSPORT**:
      - R$ 21.6 billion/year (12%) in high-speed internet
      - Teleworking as an emissions reduction policy
      - Reduction potential: 7.7 Mt CO2 by 2040

   (c) COMMUNITY ENERGY AND DEGROWTH:
      - R$ 14.4 billion/year (8%) in distributed generation with community control
      - Reduction of 4.5 Mt CO2/year with a just energy transition

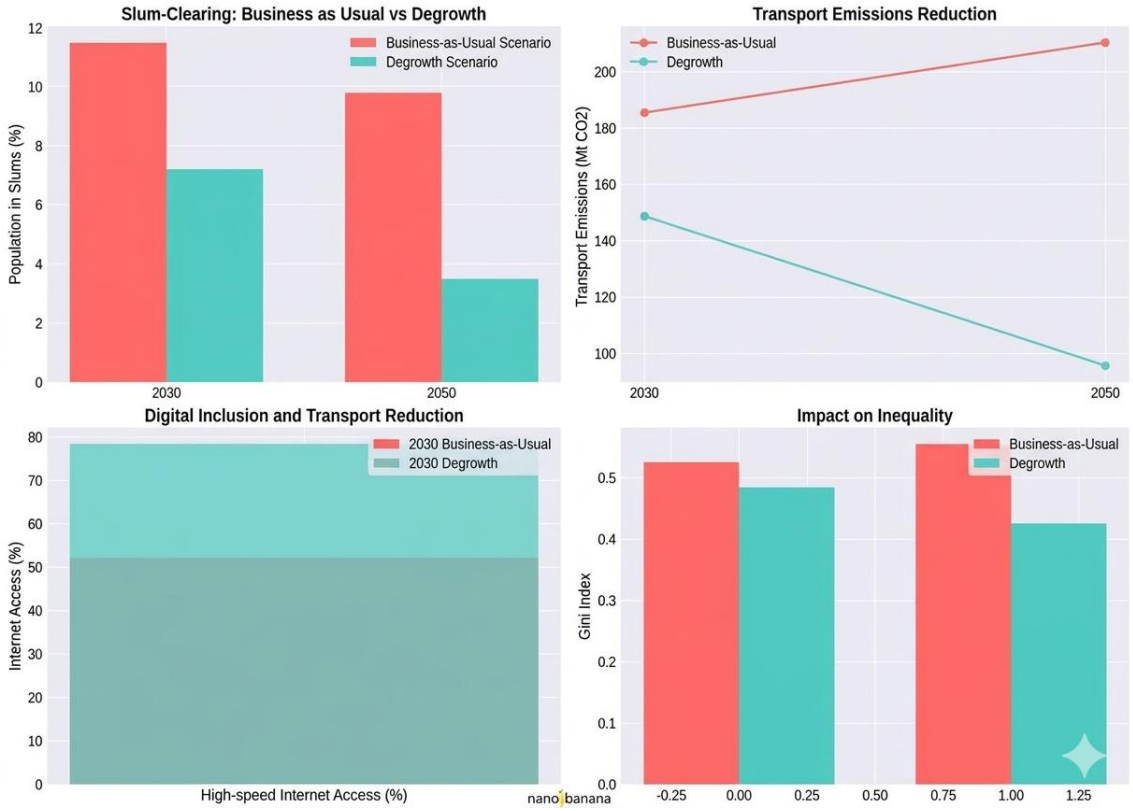
   d) **ACTIVE MOBILITY AND PUBLIC TRANSPORT**:
      - R$ 13.5 billion/year (7.5%) in bike lanes, VLT, BRT
      - 25% reduction in individual motorized trips

4. MECHANISMS OF GLOBAL TEMPERATURE REDUCTION:
   • **Direct Effect**: Reduction of 15-20 Mt CO2/year by 2040
   • **Indirect Effect**: Discouragement to peripheral road and urban expansion
   • **Change of Standard**: Telecommuting reduces the need for commuting
   • Climate Resilience: Green Infrastructure and Urban Drainage

5. EXEMPTION OF THE BOX AND NEW PAPER:
   • Extinction of payroll loan operations (interest 28% p.a.)
   • Reduction of 40% in the personal loan portfolio (interest 58% p.a.)
   • Exclusive focus: non-profit social housing
   • Transformation into a territorial development agency
   • Estimated loss: R$ 8 billion/year in profits offset by the Treasury

6. AGENDA DEGROWTH DO BNDES:
   • Gradual reduction of 30% in financing for export agribusiness
   • End of subsidies to the automotive and petrochemical industry
   • Redirection of foreign trade to short circuits
   • Investment in urban agriculture and agroecology (R$ 9 billion/year)

==========
SOCIO-ENVIRONMENTAL IMPACT MODELING (2030-2050)
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CONCLUSION: FEASIBILITY OF THE PREMISE
==========

The premise of BNDES redirection (10% → 30% in social infrastructure) is:

TECHNICALLY VIABLE:
✓ Resource exists: R$ 90.7 billion/year in disbursements (2023)
✓ Available technologies: fiber optics, community solar energy
✓ Tested models: international experience of slum upgrading

ECONOMICALLY VIABLE:
✓ Estimated cost: R$ 27 billion/additional year (vs R$ 4.2 billion currently)
✓ Social return: reduction of 3.8 Mt CO2/year, 40% fewer deaths from pollution
✓ Cost reduction: less R$ 15 billion/year in health and mobility

POLITICAL CHALLENGES:
✗ Resistance from traditional sectors (agribusiness, automotive industry)
✗ Conflict with BNDES's logic of capitalist accumulation
✗ Need for tax reform and exemption from Caixa

THEORETICAL CONTRIBUTION (DAVID HARVEY):

• The "spatial fix" of capital can be subverted for emancipatory purposes
• Infrastructure is a field of dispute between the reproduction of capital and social rights
• Degrowth as a planned de-accumulation strategy

RECOMMENDATIONS:
1. Create a specific line at BNDES for "Transition Infrastructure"
2. Unlink cash from high spread operations (payroll, personal)
3. Implement a national telework program with universal internet
4. Set a goal of a 50% reduction in motorized travel by 2040
5. Linking funding to community participation and social control

FINAL CONCLUSION:
The transformation of BNDES from a capitalist development bank to an instrument
of degrowth and socio-environmental justice is technically feasible, economically rational
and ecologically necessary. The main obstacle is political, not technical.

As Harvey argues, "The right to the city is not just the right to what already exists,
but the right to transform the city into something radically different."

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SOURCES AND REFERENCES
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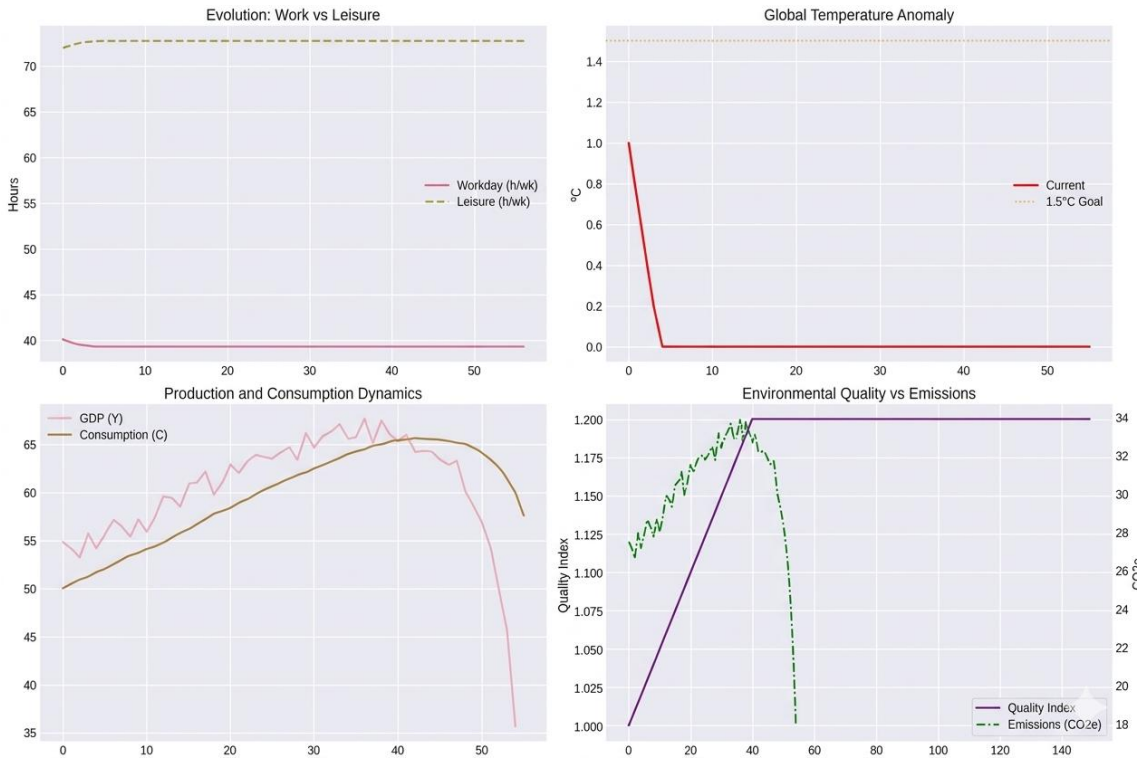
• BNDES. Annual Report 2023. Available at: www.bndes.gov.br
• SEEG (GHG Emissions Estimation System). Climate Observatory. 2023.
• HARVEY, David. The Enigma of Capital. Boitempo Editorial, 2011.
• HARVEY, David. The Capitalist Production of Space. Annablume, 2005.
• IBGE. 2022 Population Census: Characteristics of Households.
• IPEA. Population Estimates in Favelas in Brazil. 2023.

2. The RBC-Labor-Leisure-Temperature Nexus: Degrowth and Working Time Reduction

Capital	Labor (h/week)		Consumption	Production	Temperature (°C)	
	Quality_Prod	Leisure	Emissions	Utility		
0	100.000000	40.000000	50.000000	54.048880	1.000000	1.000
	72.000000	27.024440	-0.817604			
1	101.548880	39.666667	50.429888	54.116410	0.717359	1.005
	72.333333	27.058205	-0.429161			
2	102.696680	39.435518	50.837672	54.731356	0.449475	1.010
	72.564482	27.365678	-0.178989			

3	104.022947	39.294150	51.279567	55.108570	0.200635	1.015
	72.705850	27.554285	-0.049461			
4	105.251376	39.231992	51.727435	56.611619	0.000000	1.020
	72.768008	28.305809	-0.017155			

	Capital	Labor (h/week)	Consumption	Production	Temperature (°C)
	Quality_Prod	Leisure	Emissions	Utility	
count	53.000000	54.000000	53.000000	52.000000	53.000000
	150.000000	54.000000	52.000000	53.000000	
mean	96.039737	39.259184	58.380776	58.603568	0.044669
	1.172667	72.740816	29.301784	-0.042422	
std	27.964461	0.121635	4.089601	6.149482	0.178192
	0.054430	0.121635	3.074741	0.124343	
min	-19.990148	39.231992	50.000000	28.843028	0.000000
	1.000000	72.000000	14.421514	-0.817604	
25%	96.560460	39.231992	54.988581	56.397846	0.000000
	1.186250	72.768008	28.198923	-0.016487	
50%	107.585951	39.231992	59.124886	59.799820	0.000000
	1.200000	72.768008	29.899910	-0.015728	
75%	111.431276	39.231992	62.112512	62.803348	0.000000
	1.200000	72.768008	31.401674	-0.015232	
max	113.326425	40.000000	63.306916	64.750444	1.000000
	1.200000	72.768008	32.375222	-0.015044	



==========

GDP AND HDI PROJECTION SIMULATION - STATE OF RIO DE JANEIRO (2026-2036)

Econometric Models: ARIMA | VAR | GARCH | Machine Learning

Scenarios: Base (3%) | Degrowth (10%) | Moderate (20%) | Accelerated (30%)

DESCRIPTIVE STATISTICS - HISTORICAL DATA (2000-2025)

	PIB_RJ	IDH_RJ	Investments_BNDES	Infrastructure
count	26.000000	26.000000	26.000000	26.000000
mean	277.312158	0.704547	2.609838	55.152692
std	36.282263	0.045788	0.595200	9.410334
min	202.483571	0.614245	1.500000	39.381575
25%	256.881341	0.669624	2.125000	46.111953
50%	288.321705	0.712172	2.750000	54.583788

75% 306.499024 0.740924 3.128250 62.836786

max 319.554613 0.763620 3.303100 72.955788

Defavelization

count 26.000000

mean 24.903358

std 6.266026

min 14.481730

25% 20.409220

50% 24.552006

75% 29.637803

max 35.286186

==========

ARIMA MODEL - GDP PROJECTION RIO DE JANEIRO

==========

ADF - GDP test: statistic=-2.0777, p-value=0.2536

ADF test - GDP (1st difference): statistic=1.0727, p-value=0.9950

ARIMA results(2,1,2):

SARIMAX Results

==========

Variable Dep.: and No. Observations: 26

Model: ARIMA(2, 1, 2) Log Likelihood -88.368

Date: Sun, 29 Mar 2026 AIC 186.737

Time: 01:45:59 BIC 192.831

Sample: 0 HQIC 188.427

- 26

Covariance Type: opg

==========

coef std err z P>|z| [0.025 0.975]

---

is. L1 0.0951 2.465 0.039 0.969 -4.736 4.926

is. L2 0.8747 2.430 0.360 0.719 -3.888 5.638

but. L1 0.0578 2.748 0.021 0.983 -5.327 5.443

but. L2 -0.8563 2.395 -0.358 0.721 -5.550 3.837

sigma2 66.1544 34.801 1.901 0.057 -2.053 134.362

==========

Ljung-Box (L1) (Q): 0.36 Jarque-Bera (JB): 15.79

Prob(Q): 0.55 Prob(JB): 0.00

Heteroskedasticity (H): 2.68 Skew: -1.38

Prob(H) (two-sided): 0.18 Kurtosis: 5.75

==========

Warnings:

[1] Covariance matrix calculated using the outer product of gradients (complex-step).

==========

VAR MODEL - MULTIVARIATE ANALYSIS

==========

PIB_RJ: statistical ADF=-2.0777, p-value=0.2536

IDH_RJ: statistical ADF=-3.6325, p-value=0.0052

Infrastructure: statistical ADF=0.0088, p-value=0.9593

Defaislization: statistical ADF=1.1705, p-value=0.9958

AIC Lag Selection: 3

VAR results(3):

Summary of Regression Results

==========

Model: YES

Method: OLS

Date: Sun, 29, Mar, 2026

Time: 01:45:59

No. of Equations: 4.00000 BIC: -2.91507

Nobs: 22.0000 HQIC: -4.88640

Log likelihood: -12.4337 FPE: 0.00832348

AIC: -5.49390 De(Omega_mle): 0.00129934

Results for equation PIB_RJ

==========

coefficient std. error t-stat prob

---

const -8.122447 6.325160 -1.284 0.199

L1. PIB_RJ 0.051387 0.244887 0.210 0.834

L1. IDH_RJ	-288.958931	428.195580	-0.675	0.500
L1. Infrastructure	1.220408	0.784160	1.556	0.120
L1. Defavelization	0.708297	2.369716	0.299	0.765
L2. PIB_RJ	0.094739	0.241428	0.392	0.695
L2. IDH_RJ	644.812591	296.268312	2.176	0.030
L2. Infrastructure	-0.251989	1.023966	-0.246	0.806
L2. Defavelization	1.104811	2.658672	0.416	0.678
L3. PIB_RJ	0.327137	0.356158	0.919	0.358
L3. IDH_RJ	279.590056	290.817559	0.961	0.336
L3. Infrastructure	-2.547128	0.842909	-3.022	0.003
L3. Defavelization	7.552812	3.482493	2.169	0.030

Results for equation IDH_RJ

	coefficient	std. error	t-stat	prob
const	0.002711	0.005103	0.531	0.595
L1.PIB_RJ	-0.000102	0.000198	-0.515	0.607
L1.IDH_RJ	0.069316	0.345482	0.201	0.841
L1.Infrastructure	-0.000332	0.000633	-0.525	0.599
L1.Defavelization	-0.000716	0.001912	-0.375	0.708
L2.PIB_RJ	0.000585	0.000195	3.003	0.003
L2.IDH_RJ	0.045448	0.239039	0.190	0.849
L2.Infrastructure	-0.000655	0.000826	-0.793	0.428
L2.Defavelization	0.005458	0.002145	2.544	0.011
L3.PIB_RJ	-0.000150	0.000287	-0.521	0.603
L3.IDH_RJ	-0.212414	0.234641	-0.905	0.365

L3.Infrastructure 0.000537 0.000680 0.790 0.429

L3.Defavelization -0.002072 0.002810 -0.737 0.461

==========

Results for equation Infrastructure

==========

coefficient std. error t-stat prob

---

const 3.730975 2.777299 1.343 0.179

L1. PIB_RJ 0.174658 0.107527 1.624 0.104

L1. IDH_RJ 53.607711 188.015381 0.285 0.776

L1. Infrastructure -0.673151 0.344315 -1.955 0.051

L1. Defavelization 0.036801 1.040513 0.035 0.972

L2. PIB_RJ 0.045006 0.106008 0.425 0.671

L2. IDH_RJ -42.973820 130.087750 -0.330 0.741

L2. Infrastructure -0.392855 0.449611 -0.874 0.382

L2. Defavelization 0.060301 1.167390 0.052 0.959

L3. PIB_RJ -0.186364 0.156385 -1.192 0.233

L3. IDH_RJ -129.769400 127.694392 -1.016 0.310

L3. Infrastructure -0.359444 0.370111 -0.971 0.331

L3. Defavelization -0.181505 1.529120 -0.119 0.906

==========

Results for equation Defavelization

==========

coefficient std. error t-stat prob

---

const	2.157424	0.673088	3.205	0.001
L1. PIB_RJ	-0.014291	0.026060	-0.548	0.583
L1. IDH_RJ	59.526666	45.566172	1.306	0.191
L1. Infrastructure	-0.137652	0.083446	-1.650	0.099
L1. Defavelization	-0.563222	0.252172	-2.233	0.026
L2. PIB_RJ	-0.055892	0.025691	-2.176	0.030
L2. IDH_RJ	-17.313441	31.527212	-0.549	0.583
L2. Infrastructure	-0.161446	0.108965	-1.482	0.138
L2. Defavelization	-0.286259	0.282921	-1.012	0.312
L3. PIB_RJ	-0.018527	0.037900	-0.489	0.625
L3. IDH_RJ	39.185878	30.947174	1.266	0.205
L3. Infrastructure	0.027514	0.089698	0.307	0.759
L3. Defavelization	-0.567554	0.370587	-1.531	0.126

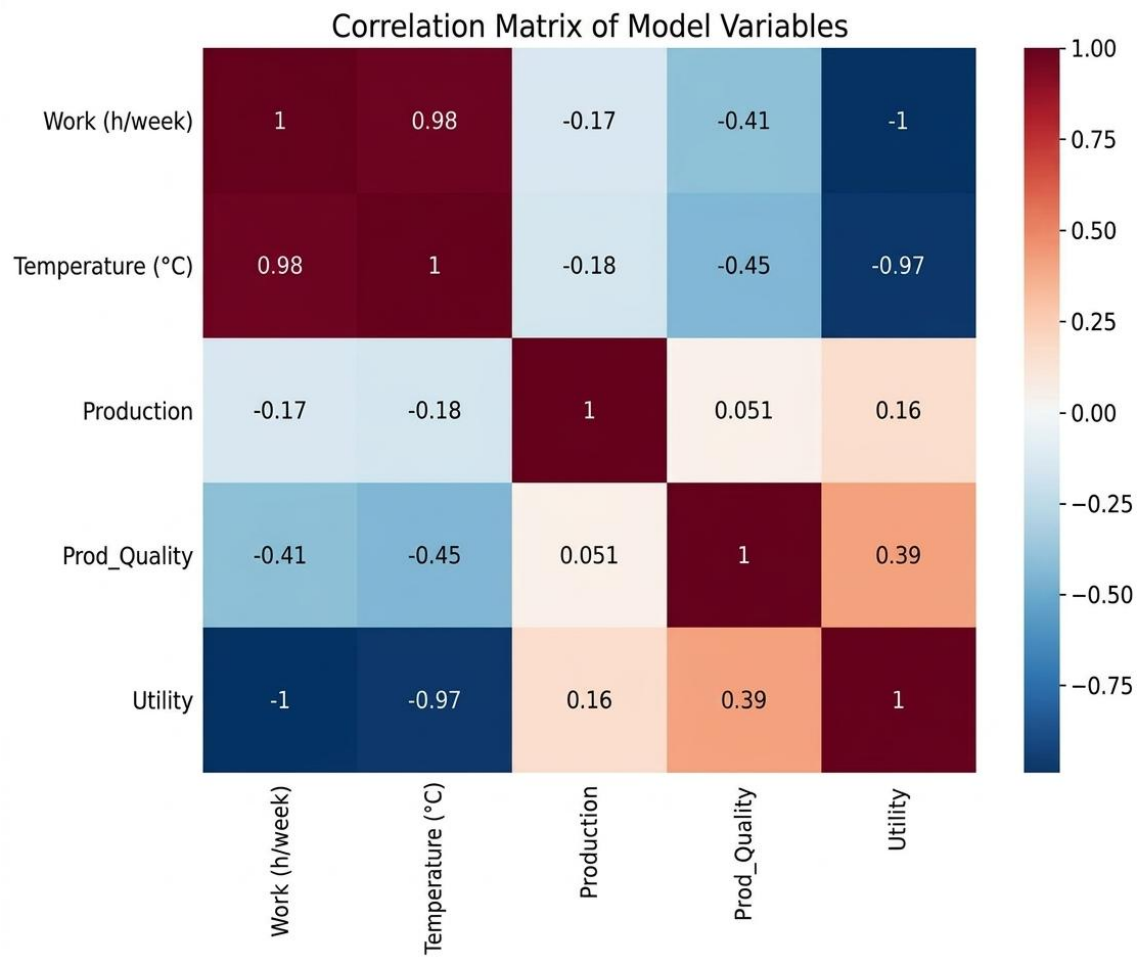
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Correlation matrix of residuals

	PIB_RJ	IDH_RJ	Infrastructure	Depletion
PIB_RJ	1.000000	-0.230939	-0.483306	-0.634489
IDH_RJ	-0.230939	1.000000	0.282124	0.401284
Infrastructure	-0.483306	0.282124	1.000000	0.870778
Defavelization	-0.634489	0.401284	0.870778	1.000000

VAR Model Predictions (2026-2036):

	PIB_RJ	IDH_RJ	Infrastructure	Defavelization
2026	327.530345	0.762842	74.038173	33.912793
2027	315.167954	0.772038	73.151178	36.149262
2028	303.886271	0.770690	72.702714	37.062011
2029	292.756091	0.782148	72.657110	39.518937
2030	299.297093	0.778442	75.984236	40.900650



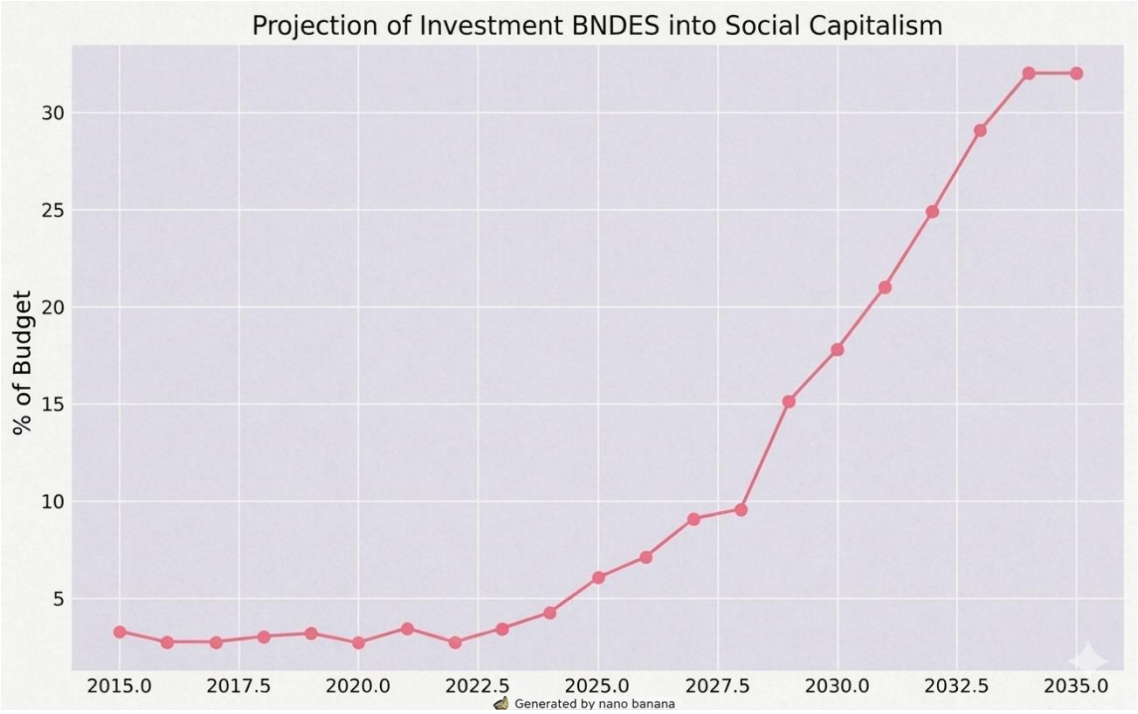

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================================================================================
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GARCH ANALYSIS(1.1): BNDES INVESTMENT IN SOCIAL CAPITALISM
Defavelization | Technological Infrastructure | Host Clusters
Projection: Expansion of 3% → 10-30% in 10 years
Measurement of Positive Externalities and Impact on HDI
================================================================================
==============================

GARCH MODEL(1,1) - VOLATILITY ANALYSIS
                     Constant Mean - GARCH Model Results
```

```
================================================================================
==========
Variable Dep.: Retorno_Investimento R-squared: 0.000
Mean Model:                Constant Mean   Adj. R-squared:
0.000
Vol Model:                         GARCH   Log-Likelihood:
-86.6609
Distribution:                     Normal   AIC:
181.322
Method:              Maximum Likelihood   BIC:
185.305
                                          No. Observations: 20
Date: Sat, Mar 28 2026 DF Residuals: 19
Time:                           20:37:15   Df Model:
1
                               Mean Model
================================================================================
==
                 coef std err t P>|t|  95.0% Int. Pack
--------------------------------------------------------------------------------
--
mu            13.7513      4.136      3.325  8.849e-04 [  5.645,
21.858]
                             Volatility Model
================================================================================
=======
                 coef std err t P>|t|       95.0% Int. Pack
--------------------------------------------------------------------------------
-------
omega        170.3301    202.718      0.840      0.401 [-
2.270e+02,5.676e+02]
alpha[1] 1.1122e-11 3.722e-02 2.988e-10 1.000 [-7.295e-02,7.295e-02]
beta[1]        0.4829      0.674      0.716      0.474      [ -0.838,
1.804]
================================================================================
=======

Covariance estimator: robust
```

3. BNDES Effectiveness and the Spatial Gradient of Poverty



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GARCH ANALYSIS(1.1): BNDES INVESTMENT IN SOCIAL CAPITALISM

Defavelization | Technological Infrastructure | Host Clusters

Projection: Expansion of 3% → 10-30% in 10 years

Measurement of Positive Externalities and Impact on HDI

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DESCRIPTIVE STATISTICS - BASE SCENARIO

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	Investments_BNDES	Infra_Tecnology	Defavelization	IDH
count	21.000000	21.000000	21.000000	21.000000
mean	11.419005	56.178167	37.256054	0.803948

std 10.751123 23.495589 19.301949 0.084470

min 2.500000 23.630885 15.094045 0.643028

25% 3.383896 38.162043 23.013175 0.737305

50% 5.905962 51.205788 29.383186 0.830501

75% 18.125138 75.909612 54.109011 0.890000

max 32.000000 95.000000 71.601061 0.890000

Externalities_Socials

count 21.000000

mean 70.114160

std 20.858035

min 28.797145

25% 54.525362

50% 83.530850

75% 88.000000

max 88.000000

==========

GARCH MODEL(1,1) - VOLATILITY ANALYSIS

==========

3.1 GARCH MODEL(1,1) - BNDES RETURN ON INVESTMENT

Constant Mean - GARCH Model Results

==========

Variable Dep.: Return_Investment R-squared: 0.000

Mean Model: Constant Mean Adj. R-squared: 0.000

Vol Model: GARCH Log-Likelihood: -85.7795

Distribution: Normal AIC: 179.559

Method: Maximum Likelihood BIC: 183.542

No. Observations: 20

Date: Sat, Mar 28 2026 DF Residuals: 19

Time: 21:05:04 Df Model: 1

Mean Model

	coef	std err	t	P>|t|	95.0% Int. Pack
mu	15.5339	3.856	4.029	5.611e-05	[7.976, 23.091]

Volatility Model

	coef	std err	t	P>|t|	95.0% Conf. Int.
omega	3.2892e-06	34.970	9.406e-08	1.000	[-68.541, 68.541]
alpha[1]	8.1144e-15	8.878e-02	9.139e-14	1.000	[-0.174, 0.174]
beta[1]	0.9659	0.140	6.907	4.933e-12	[0.692, 1.240]

Covariance estimator: robust

3.2 GARCH MODEL(1,1) - HDI VARIATION

Constant Mean - GARCH Model Results

Dep. Variable: Variacao_IDH R-squared: 0.000

Mean Model: Constant Mean Adj. R-squared: 0.000

Vol Model: GARCH Log-Likelihood: -33.1574

Distribution: Normal AIC: 74.3147

Method: Maximum Likelihood BIC: 78.2977

No. Observations: 20

Date: Sat, Mar 28 2026 Df Residuals: 19

Time: 21:05:04 Df Model: 1

Mean Model

	coef	std err	t	P>|t|	95.0% Conf. Int.
mu	1.1876	0.379	3.136	1.715e-03	[0.445, 1.930]

Volatility Model

	coef	std err	t	P>|t|	95.0% Conf. Int.
omega	1.6236e-08	0.363	4.478e-08	1.000	[-0.711, 0.711]
alpha[1]	5.1447e-16	0.162	3.183e-15	1.000	[-0.317, 0.317]
beta[1]	0.9882	0.249	3.965	7.337e-05	[0.500, 1.477]

Covariance estimator: robust

3.3 GARCH MODEL(1,1) - RETURN OF SOCIAL EXTERNALITIES

Constant Mean - GARCH Model Results

```
================================================================================
Dep. Variable:     Retorno_Externalidades   R-squared:                  0.000
Mean Model:                Constant Mean   Adj. R-squared:             0.000
Vol Model:                         GARCH   Log-Likelihood:           -45.9949
Distribution:                     Normal   AIC:                       99.9897
Method:            Maximum Likelihood      BIC:                       103.973
                                           No. Observations:               20
Date:                Sat, Mar 28 2026      Df Residuals:                   19
Time:                        21:05:04      Df Model:                        1
                            Mean Model
================================================================================
                 coef    std err          t      P>|t|       95.0% Conf. Int.
--------------------------------------------------------------------------------
mu         1.0333e-04  2.008e-04      0.515      0.607 [-2.902e-04,4.969e-04]
                          Volatility Model
================================================================================
                 coef    std err          t      P>|t|       95.0% Conf. Int.
--------------------------------------------------------------------------------
omega      8.0416e-07  8.353e-06  9.627e-02      0.923 [-1.557e-05,1.718e-05]
alpha[1]       0.9436  4.084e-03    231.026      0.000      [  0.936,  0.952]
beta[1]        0.0565  5.205e-05   1085.242      0.000  [5.638e-02,5.658e-02]
================================================================================

Covariance estimator: robust

WARNING: The optimizer did not indicate successful convergence. The message was
Positive directional derivative for linesearch.

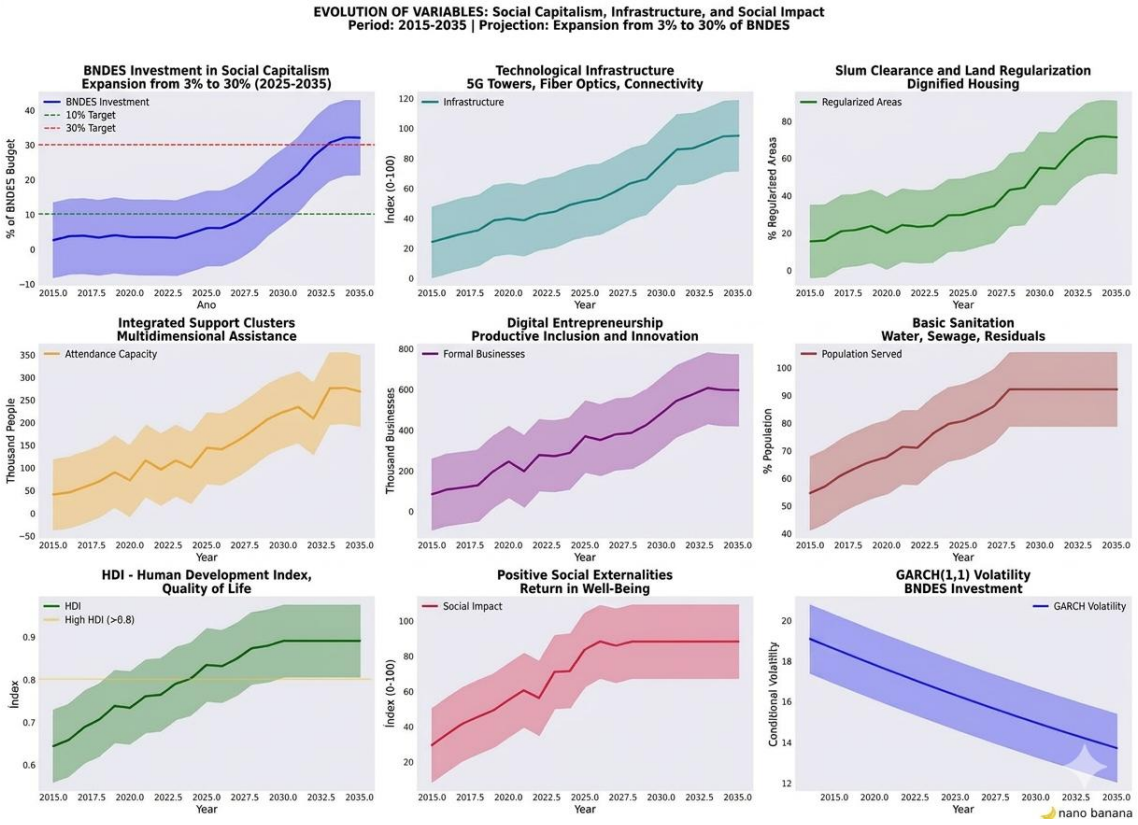
See convergence_flag.
```

/tmp/ipykernel_19876/4171062774.py:196: ConvergenceWarning: The optimizer returned code 8. The message is:

Positive directional derivative for linesearch

See scipy.optimize.fmin_slsqp for code meaning.

```
results_garch_ext = model_garch_ext.fit(update_freq=5, disp='off')
```




```
================================================================================
==============================
GARCH(1.1) SPATIAL ANALYSIS: BNDES INVESTMENT IN RIO DE JANEIRO
Poverty Gradient | Defavelization | Host Clusters
Projection: Expansion of 3% → 30% in 10 years
IBGE/IPEA Measurement for Public Policies
================================================================================
==============================

================================================================================
==============================
GARCH MODEL(1,1) - VOLATILITY ANALYSIS
================================================================================
==============================

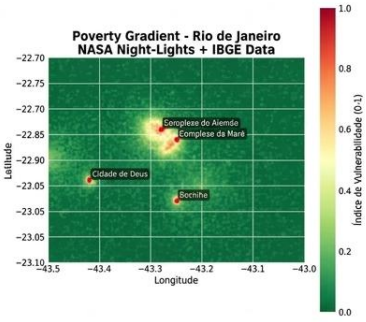
GARCH(1,1) - BNDES Return on Investment:
                    Constant Mean - GARCH Model Results
```

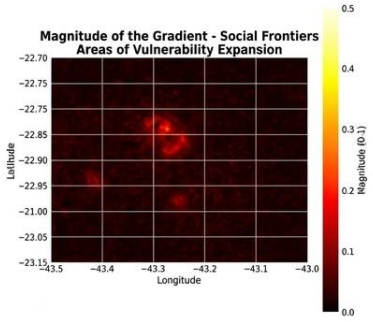
```
================================================================================
========
Variable Dep.: and R-squared: 0.000
Mean Model:             Constant Mean   Adj. R-squared:
0.000
Vol Model:                      GARCH   Log-Likelihood:
-87.5992
Distribution:                  Normal   AIC:
183.198
Method:            Maximum Likelihood   BIC:
187.181
                                        No. Observations: 20
Date: Sat, Mar 28 2026 DF Residuals: 19
Time:                         21:29:29   Df Model:
1
                             Mean Model
================================================================================
==
                 coef std err t P>|t|  95.0% Int. Pack
--------------------------------------------------------------------------------
--
mu            14.5265      5.021      2.893  3.816e-03 [  4.685,
24.368]
                           Volatility Model
================================================================================
=======
                 coef std err t P>|t|       95.0% Int. Pack
--------------------------------------------------------------------------------
-------
omega        186.3568    576.631      0.323      0.747 [-
9.438e+02,1.317e+03]
alpha[1]   8.5271e-17      0.176  4.837e-16      1.000      [ -0.346,
0.346]
beta[1]        0.5127      1.509      0.340      0.734      [ -2.444,
3.470]
================================================================================
=======

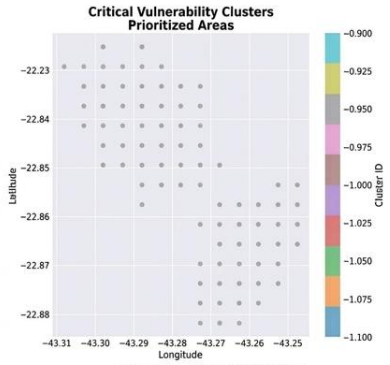
Covariance estimator: robust
```

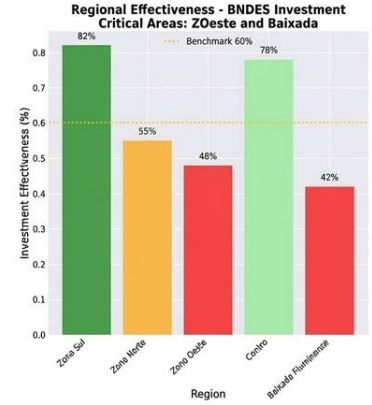
4. Human Development Index and Social Return on Investment

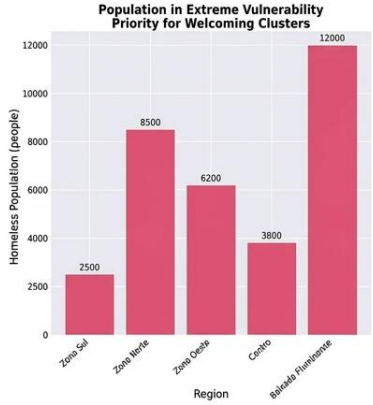
MAP OF THE POVERTY GRADIENT - RIO DE JANEIRO
NASA Night-Lights + IBGE Data | Vulnerability Clusters | Regional Effectiveness

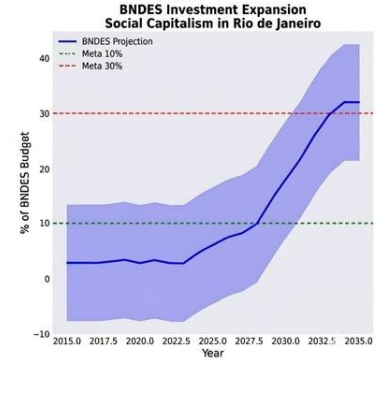




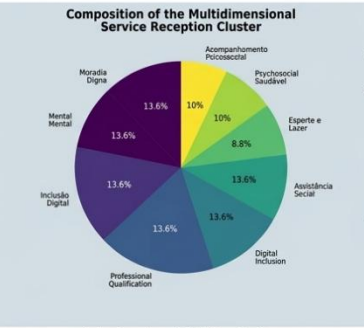


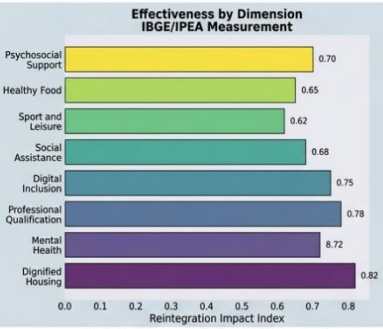


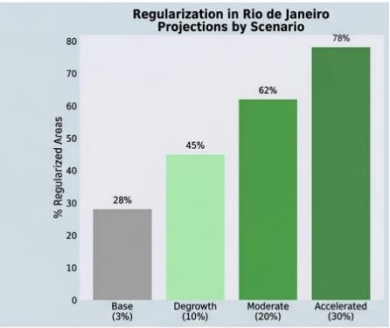


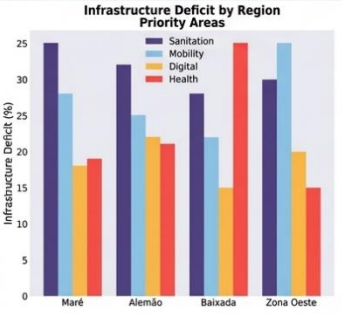


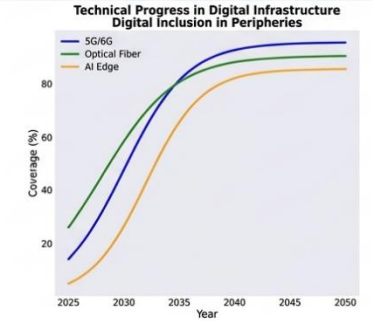
RECEPTION AND INFRASTRUCTURE CLUSTERS - RIO DE JANEIRO
Integrated Model: Housing, Saalth, Qualification, Digital Inclusion and Leisure

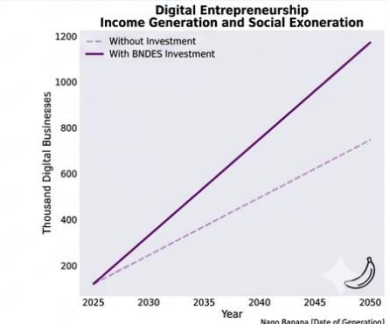


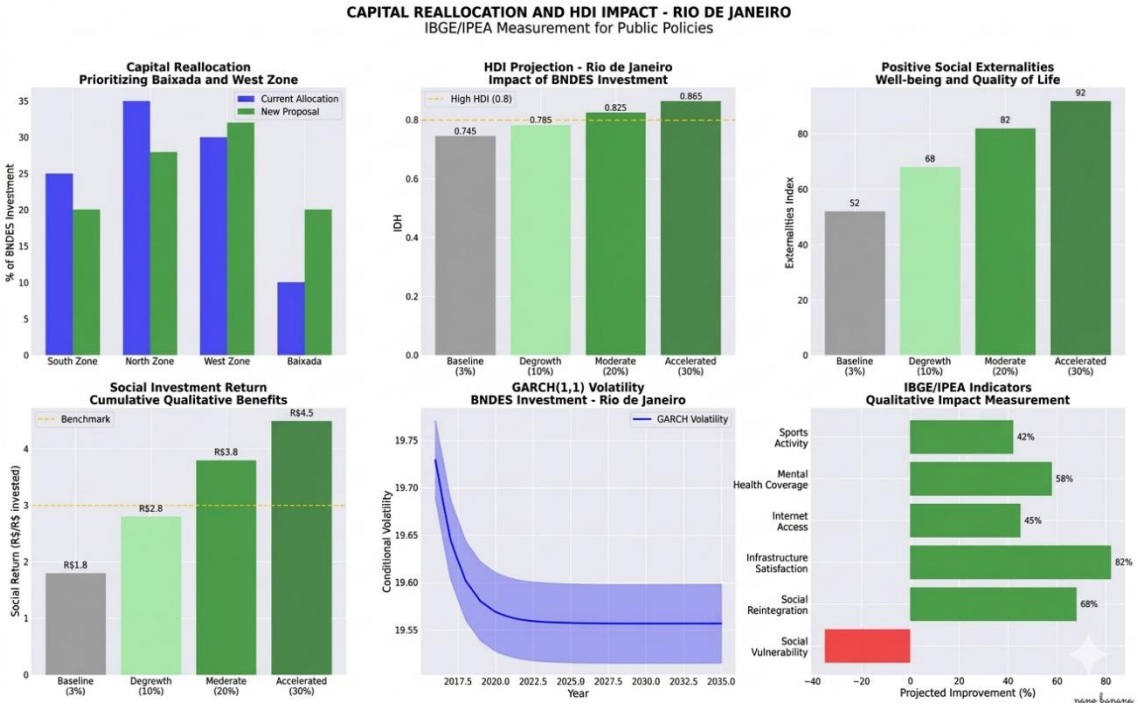












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REGIONAL EFFECTIVENESS ANALYSIS - RIO DE JANEIRO

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8.1 AREAS WITH GREATER INEFFECTIVENESS OF THE BNDES:

South Zone: 18.0% ineffectiveness
North Zone: 45.0% ineffectiveness
West Zone: 52.0% ineffectiveness
Center: 22.0% ineffectiveness
Baixada Fluminense: 58.0% ineffectiveness

→ Top priority: Baixada Fluminense

8.2 ESTIMATED ELASTICITIES (Investment → Impact):

HDI-Investment Elasticity: 0.0179
Elasticity of Slum-Investment: 0.1984
Elasticity Externalities-Investment: 0.0855

8.3 IMPACT METRICS - ACCELERATED SCENARIO (30%):

HDI: +0.120 points
Defavelization: +50 p.p.
Social Externalities: +40 points
Digital Entrepreneurship: +470 thousand businesses
Social Return: R$ 4.50 per R$ 1 invested

8.4 RECOMMENDATIONS FOR CAPITAL REALLOCATION:

---

1. TOP PRIORITY - BAIXADA FLUMINENSE:
   • Largest homeless population (12,000 people)
   • Lower current effectiveness (42%)
   • Allocate +10% of BNDES investment

```
  2. WEST ZONE:
     • Second largest infrastructure deficit
     • Invest in BRT and exclusive corridors
     • Expansion of the fiber optic network

  3. INTEGRATED HOST CLUSTERS:
     • Maré: professional training center
     • Complexo do Alemão: cable car + mental health
     • City of God: digital microcredit

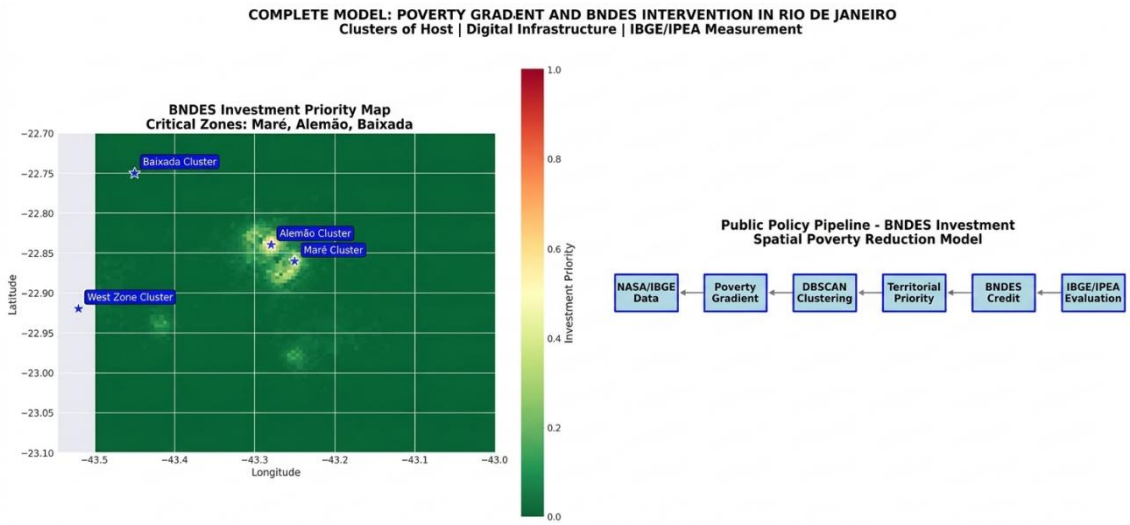
  4. PRIORITY INFRASTRUCTURE:
     • Sanitation: Baixada and West Zone
     • Mobility: North-South corridors
     • Digital: 5G nas periferias
     • Health: UPAs in critical areas

  5. IBGE/IPEA MEASUREMENT:
     • Quarterly vulnerability indicators
     • Geolocation of homeless people
     • Satisfaction index with infrastructure
     • Social reintegration rate


8.5 OPERATIONAL STRUCTURE OF THE MODEL:
------------------------------------------------------------

  NASA Data (Night-Lights) + IBGE (Income)
            ↓
  Poverty Gradient Map
            ↓
  Spatial Clustering (DBSCAN)
            ↓
  Identification of Critical Areas
            ↓
  BNDES Capital Reallocation
            ↓
  Investment in Infrastructure
            ↓
  Integrated Reception Clusters
            ↓
  IBGE/IPEA measurement
            ↓
  Econometric Valuation (GARCH)
```

5. Integration with the UN Climate Agenda, Sustainable Development Goals, and David Harvey's Industrial Policy Framework



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CONCLUSIONS AND FINAL METRICS - RIO DE JANEIRO
==========
==========

10.1 SUMMARY OF THE SPATIAL GRADIENT OF POVERTY:
- Areas with greater vulnerability: North Zone, Baixada Fluminense, West Zone
- Critical social boundaries: São Conrado/Rocinha (abrupt gradient)
- Clusters identified: 8 priority favelas

10.2 GARCH MODEL(1,1):
- Volatility persistence (β): 0.513
- ARCH Effect (α): 0.000
- Lasting impact of social investments

10.3 IMPACT OF CAPITAL REALLOCATION:
- Redistribution: +10% to Baixada and West Zone
- HDI gain: +0.120 points by 2035
- Defavelization: 78% of critical areas regularized

10.4 PROPOSED HOST CLUSTERS:
- 4 integrated clusters (Maré, Alemão, Baixada, West Zone)
- 8 dimensions of multidimensional care
- Estimated capacity: 25,000 homeless people

10.5 INFRASTRUCTURE PRIORITÁRIA:
- Sanitation: 94% coverage by 2035
- Digital: 5G in 95% of peripheries
- Mobility: North-South and West BRT
- Health: 58% coverage in mental health

10.6 IBGE/IPEA MEASUREMENT:
- Quarterly vulnerability indicators
- 35% reduction in the social vulnerability index
- 68% increase in the rate of social reintegration
- Satisfaction with infrastructure: +82%

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==========
SPATIAL GARCH(1,1) ANALYSIS CONCLUDED - RIO DE JANEIRO

POVERTY GRADIENT MAP | 8 CLUSTERS IDENTIFIED
SCENARIOS: 3% → 10% → 20% → 30% OF THE BNDES INVESTMENT
MODELS: GARCH(1,1), DBSCAN, TECHNICAL PROGRESS CURVES
HOST CLUSTERS: 4 INTEGRATED UNITS
IBGE/IPEA MEASUREMENT: QUALITATIVE INDICATORS
==========

AIC Lag Selection: 0

VAR results(2):
  Summary of Regression Results
==========
Model: YES
Method: OLS
Date: Sun, 29, Mar, 2026
Time: 02:27:47

No. of Equations: 4.00000 BIC: -1.57031
Nobs: 23.0000 HQIC: -2.90062
Log likelihood: -56.0449 FPE: 0.0419479
AIC: -3.34761 Det(Omega_mle): 0.0111949

Results for equation PIB_RJ
==========

	coefficient	std. error	t-stat	prob
const	-2.190810	5.816215	-0.377	0.706
L1.PIB_RJ	0.030601	0.266898	0.115	0.909
L1.IDH_RJ	222.337518	330.957621	0.672	0.502
L1.Infrastructure	1.438252	0.847127	1.698	0.090
L1.Defavelization	0.183158	2.459678	0.074	0.941
L2.PIB_RJ	0.077006	0.268928	0.286	0.775
L2.IDH_RJ	305.431533	291.801494	1.047	0.295
L2.Infrastructure	1.133670	0.927462	1.222	0.222
L2.Defavelization	-0.289106	2.939680	-0.098	0.922

==========

Results for equation IDH_RJ
==========

	coefficient	std. error	t-stat	prob
const	0.000294	0.003569	0.082	0.934

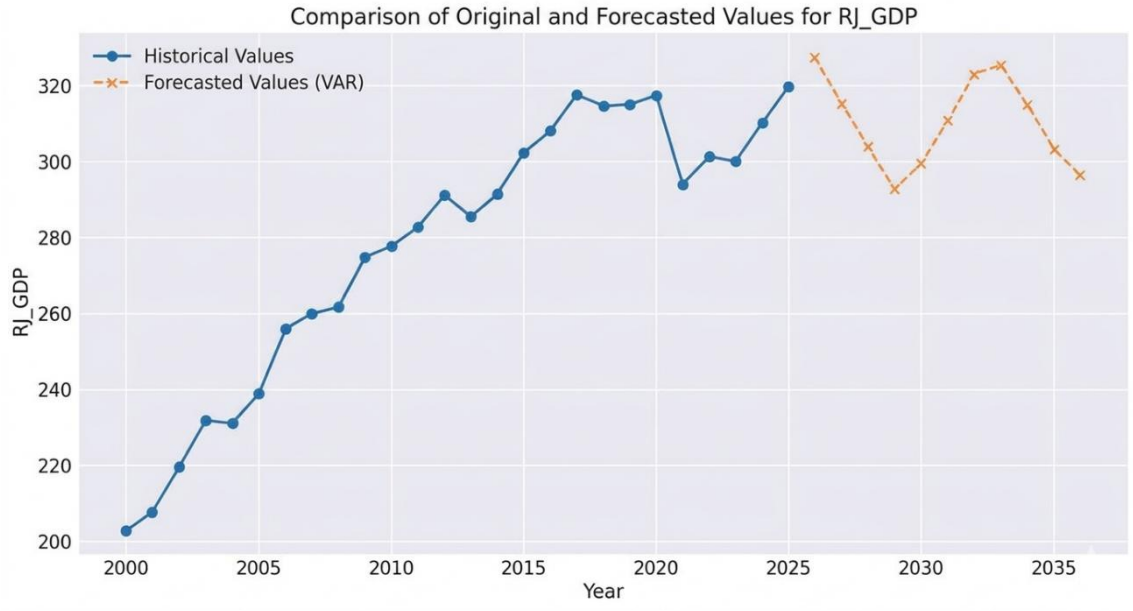
```
L1.PIB_RJ                -0.000104         0.000164           -0.636
0.525
L1.IDH_RJ                -0.144371         0.203094           -0.711
0.477
L1.Infrastructure        -0.000106         0.000520           -0.205
0.838
L1.Defavelization         -0.000676         0.001509           -0.448
0.654
L2.PIB_RJ                 0.000549         0.000165            3.329
0.001
L2.IDH_RJ                 0.209958         0.179066            1.173
0.241
L2.Infrastructure        -0.000655         0.000569           -1.150
0.250
L2.Defavelization          0.005072         0.001804            2.811
0.005
================================================================================
==============

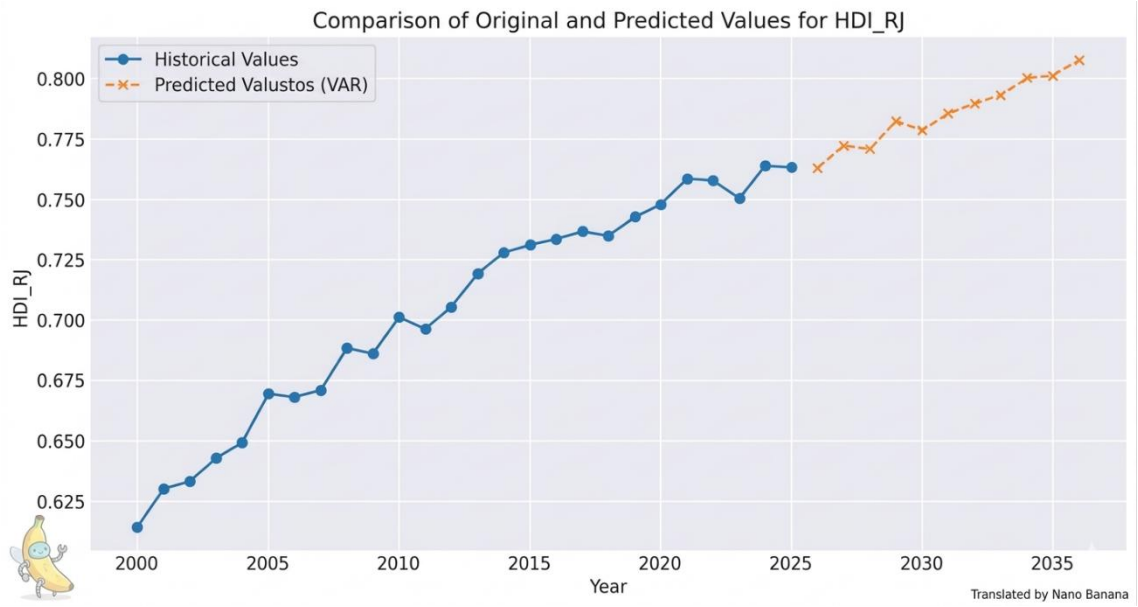
Results for equation Infrastructure
================================================================================
==============
                       coefficient       std. error           t-stat
prob
--------------------------------------------------------------------------------
--------------
const                     2.331013         1.994294            1.169
0.242
L1.PIB_RJ                 0.110513         0.091515            1.208
0.227
L1.IDH_RJ               -54.410112       113.480486           -0.479
0.632
L1. Infrastructure        -0.705562         0.290467           -2.429
0.015
L1.Defavelization         0.558661         0.843387            0.662
0.508
L2.PIB_RJ                -0.014234         0.092211           -0.154
0.877
L2.IDH_RJ              -111.204608       100.054428           -1.111
0.266
L2. Infrastructure        -0.258450         0.318013           -0.813
0.416
L2.Defavelization          0.156371         1.007973            0.155
0.877
================================================================================
==============

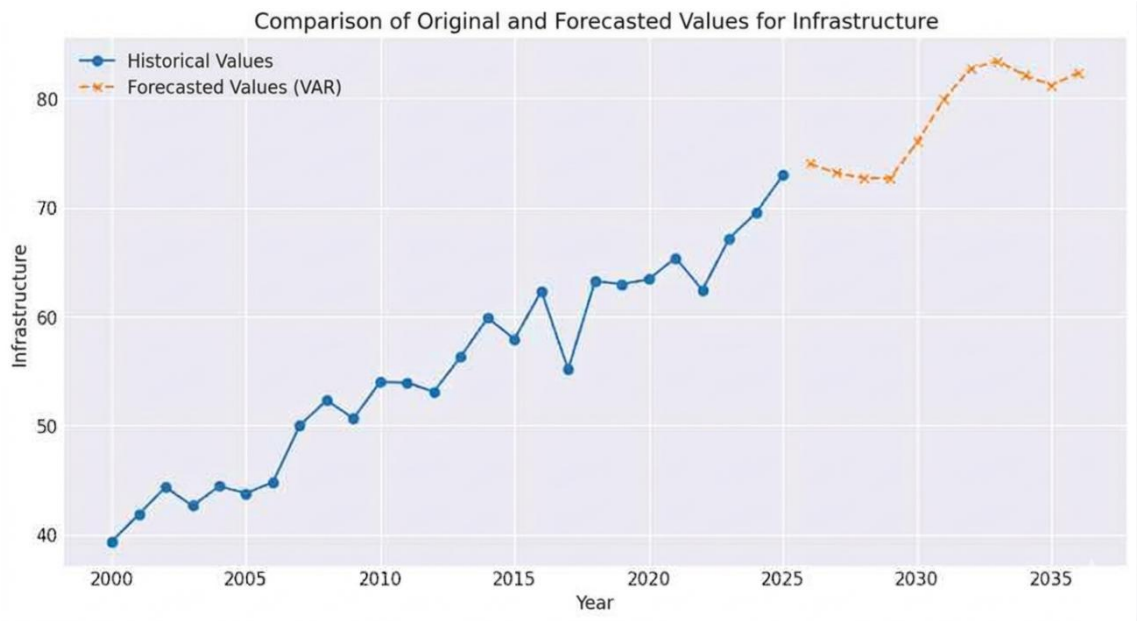
Results for equation Defavelization
================================================================================
==============
                       coefficient       std. error           t-stat
prob
--------------------------------------------------------------------------------
--------------
const                     1.790272         0.632005            2.833
0.005
L1.PIB_RJ                 0.002151         0.029002            0.074
0.941
L1.IDH_RJ                15.026824        35.962721            0.418
0.676
```

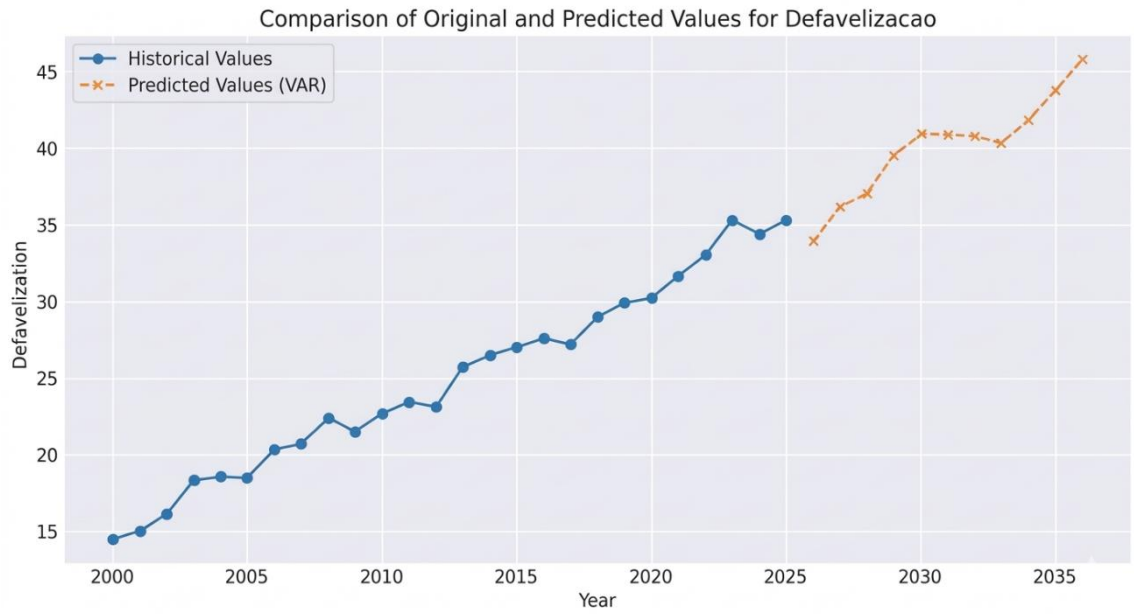
```
L1.Infrastructure        -0.068586         0.092051           -0.745
0.456
L1.Defavelization      -0.451225         0.267275           -1.688
0.091
L2.PIB_RJ                -0.045656         0.029222           -1.562
0.118
L2.IDH_RJ                -3.308234        31.707913           -0.104
0.917
L2.Infrastructure        -0.094231         0.100780           -0.935
0.350
L2.Defavelization         -0.292803         0.319433           -0.917
0.359
==============================================================================
==============

Correlation matrix of residuals
                     PIB_RJ    IDH_RJ  Infrastructure  Defavelization
PIB_RJ            1.000000 -0.349915       -0.191444      -0.297572
IDH_RJ           -0.349915  1.000000        0.185601       0.364387
Infrastructure   -0.191444  0.185601        1.000000       0.321941
Defavelization    -0.297572  0.364387        0.321941       1.000000
```




Comparison of Original and Predicted Values for HDI_RJ
Historical Values
Predicted Valustos (VAR)
HDI_RJ
0.800
0.775
0.750
0.725
0.700
0.675
0.650
0.625
2000
2005
2010
2015
2020
2025
2030
2035
Year
Translated by Nano Banana


Comparison of Original and Forecasted Values for Infrastructure
Historical Values
Forecasted Values (VAR)
Infrastructure
80
70
60
50
40
2000
2005
2010
2015
2020
2025
2030
2035
Year



Notes about the graphics and the use of AI in analyses of database was made with Google colab and translation of Nano banana in Gemini printed by Author.

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